THE JOURNAL OF PROSTHETIC DENTISTRY

Vol. 6 JULY, 1956 No. 4

THROUGH THE EYES OF THE EDITOR

John P. Frush and Roland D. Fisher discuss the personality factor as it relates to esthetics. They classify patients' personalities and suggest a corresponding personality classification of teeth. By this means, they provide refinement and individuality in their restorations. Obviously, the application of the personality factor to any given patient or his denture will require judgment, but if the concept is understood, the necessary judgment will be acquired with experience.

G. A. Lammie discusses the changes that occur in patients with aging and the effects of these changes upon the effectiveness and function of complete lower dentures. He analyzes the changes that occur in the mucosa and submucosa, the musculature, and the bone. On the basis of his analysis many denture difficulties are explained. He suggests modifications in procedures to meet specific conditions which are produced by aging. The suggestions seem to be sound.

Meyer M. Silverman discusses the procedures for using phonetics as a guide to the determination of vertical dimension of occlusion. The variation in the "closest speaking space . . . from 0 to 10 mm., in different patients" indicates that this method must be used with judgment. It is certainly a useful guide, but the results should be checked against those of other methods in order to be safe.

Victor E. Beresin and Morris Beresin discuss the various types of occlusal forms of teeth from a bio-mechanical approach. They compare natural and artificial teeth in relation to the conditions under which they function. They compare the various basic types of artificial posterior teeth and state that all of them have certain disadvantages. They suggest that posterior teeth with curved occluding surfaces will make possible their arrangement upon a curve which is in harmony with mandibular movement. This concept seems sound, but it can be developed, with teeth that have flat occlusal surfaces, by "milling" the teeth on the articulator after they have been set up. The procedure suggested for arranging the "curved" teeth would avoid the necessity for "milling" until after the dentures are processed.

Robert M. Ricketts suggests the use of cephalometrics in prosthodontic diagnosis and reports upon his research into various prosthodontic problems by cephalometric analysis. He shows the relations of the bony structures of the head to the muscular system which supports the head and moves the mandible. On the basis of his studies, he questions the premise that the mandible closes on the hinge axis from rest position. It seems apparent that there is need for distinction between what the mandible *can* do and what the mandible *does* under varying circumstances. It must be recognized that hinge movement is a *border* movement. The mandible *may or may not* be in the hinge position while it is in rest position, depending upon the particular characteristics of the individual being studied. He suggests several approaches to further study of the problems of occlusion which are worthy of consideration.

Douglas Allen Atwood discusses a cephalometric method for studying the clinical rest position of the mandible. He compares this method of measurement with other methods and finds that it has many advantages. He classes the rest position as a postural position and as such it is subject to

variability. He shows the variations to occur from patient to patient, and in the same patient. The data supplied for measurements of 42 patients seem to bear out his statements. The questions raised by this study will provide much food for thought and possibly a revision of the general concept of rest position and interocclusal distance.

W. Fenner, A. Gerber, and H. R. Mühlemann report their studies of mobility of the abutment teeth of four patients as it was affected by different clasp designs. The variations they found could be expected on the basis of an analysis of the clasps tested. The test procedure could be modified to determine the effect of different designs of partial dentures. Further work of this nature should be done before definite conclusions are drawn.

Anthony K. Kaires reports his studies of unilateral force distribution with variations in the design of a partial denture. The testing procedures were similar to those used for studying bilateral force distribution. The results seem to verify the current clinical observations regarding partial denture design.

C. W. Fairhurst, T. C. Furman, R. V. Schallhorn, E. L. Kirkpatrick, and G. Ryge report their investigation of the elastic properties of the rubber base impression material. The tests used were similar to those used for hydrocolloid materials. The results have important clinical significance, especially as they are related to techniques for using the rubber base impression materials.

Milton Silver describes a method for making impressions for fixed restorations in the rubber base impression materials and for making silver-plated dies from these impressions. The procedure involves the use of acrylic resin to bind copper bands together for making a suitable tray. The advantages of the use of these materials over reversible hydrocolloid and stone seem apparent. The time consumed in fitting the copper bands and preparing the tray may be a disadvantage.

Alexander Leff describes a method for reproducing the contours of natural teeth in full coverage restorations. The self-curing acrylic resins are used to make shells in an alginate impression. The advantages of the procedure for those situations where it can be used are obvious. The suggested use of acrylic resins for assembling the parts of restorations might cause some difficulties because of the shrinkage and warpage which occur as the resin cures.

Gerald D. Stibbs describes an impression procedure for three-quarter crowns which combines some features of an indirect technique with some features of a direct technique. It is apparent that there are many advantages in the procedure he describes.

Bruce B. Smith discusses the broader concepts of gold foil. These include modifications of the usual cavity preparations and the methods for placing gold foil in the cavities. There can be no doubt of the merit of gold foil as a restorative material. When it is used as he shows that it can be used, the advantages are obvious.

Charles Schroeter describes a simple clinical camera setup and tells how to assemble it. The cost of the parts is not prohibitive, and the equipment is practical, easy to use, and almost foolproof.

—Carl O. Boucher

WILL DENTISTRY ACCEPT THE CHALLENGE?

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IN THE JULY, 1952, ISSUE of THE JOURNAL OF PROSTHETIC DENTISTRY, Dr. M. M. House challenged the American dental profession to consider, and to establish ultimately, a centralized and educational dental museum. Dr. House pointed out that many of the wonderful collections in our colleges which are of inestimable value to dental education are now stored, or have been destroyed. In this article, I shall consider this challenge from three standpoints: (1) Does the dental profession want to accept this challenge and proceed toward the establishing of a dental museum? If the answer to this question is "No," then we can dismiss the matter from our minds and leave it to succeeding generations of dentists to review the challenge when their turn comes. If the answer is "Yes," then the next question is: (2) Can a museum be established within the not too far distant future? If the answer to this question is "No," again the matter can be shelved for this generation. However, if the answer is "Yes," a third question should be asked and answered: (3) What is our next step toward the establishing of a museum?

DO WE WANT TO ACCEPT THIS CHALLENGE?

During the past few months, I have corresponded with many members of the dental profession. Representatives of the dental trades association, laboratory interests, manufacturers, educational institutions, dental organizations, and dentists have expressed their opinions on this important matter. Although large groups of people will not agree unanimously on any principle, there is very definitely a concensus as to the desirability of hoping, at least, that a museum will be established.

A list of arguments for establishing a dental museum would be endless. However, there are several facts that we must not ignore in a consideration of whether we shall proceed toward this goal, or just wait.

1. The thinking of such men as House, Gysi, Stansbery, Hall, McCollum, and others before our generation will be lost unless we preserve their work. The present generation of active participants in the dental profession is the transitional link blending the knowledge of the past with the knowledge of the future. There is no one among us who is not proud of, and indebted to, the contributions of the past generations. What we know today is the result of two things: the knowledge that has been given to us out of the past, and our ability, initiative, and even ingenuity in the utilization of this knowledge to solve some of the problems with which we have been faced during our generation. We must pass on to those who follow this heritage that we have received.

Received for publication March 13, 1956.

2. A museum would stimulate young men to enter the field of dentistry because it would show these young men what has gone before in this field. It would offer a challenge to them to carry on this important work.

3. Such a museum would be of great interest to the public, and would serve as an educational medium in enlightening the general public as to what has gone before in dentistry, and it would ultimately show the contributions made by the present generation.

4. The great contributions that have been made by the manufacturers and research men of both the past and the present should be preserved in an organized and catalogued way in a central location.

5. In his article,[1] Dr. House stated that one of the best arguments for the establishment of such a dental museum is: "Many in our profession who have traveled a great deal, and have visited many of our dental schools and departments of research and museums, both medical and dental, and many that have privately-owned museums, will be able to visualize and appreciate how valuable a great centralized dental educational museum would be to this age of specialization. Dentists who have traveled broadly have visited many of these exhibits. But they have seen relatively few of them that could have been seen and studied in a great centralized museum, where much more detailed study would be made possible by carefully prepared legends and descriptions."

6. There is an almost "contagious enthusiasm" being developed practically without stimulation on the part of the committee. Here are some excerpts from letters received:

"I am greatly interested and wish to encourage you in this very worthwhile activity to which you are now devoting your time."

"Apparently, you have the start of a memorial for material to be placed and possibly a place to put it. It is a commendable effort and results should be of benefit to all."

"I am delighted to learn that the American Denture Society as well as the Academy of Denture Prosthetics and THE JOURNAL OF PROSTHETIC DENTISTRY are exploring the possibilities of preserving more of the memorabilia of the dental profession's history."

Although contributions have not been solicited, a small amount of money is already on deposit through the generosity of an enthusiastic supporter. While it is not my purpose to persuade on this project beyond what might be considered practicable at this time, it does seem reasonable to conclude that dentistry does recognize a need for this museum.

COULD A DENTAL MUSEUM BE ESTABLISHED?

Although there is agreement concerning the desirability of this project, yet there is doubt in some minds as to whether or not it is possible. All great movements and projects of history were launched with doubt in the minds of many people. At times, doubt is good because it tends to serve as a restraining influence to prevent our rushing foolishly into a project without adequate consideration of the difficulties of the plan, and a carefully prepared outline of the methodology to be followed.

The difficulty of executing this project seems to fall into three main divisions: Could we get the equipment? Could the project be financed? Could we find a suitable location?

Although it is impossible to say, at this time, just how much equipment would be donated to such a museum, it is certainly reasonable to assume that the dental memorabilia will be available in increasing amounts when and if such a museum is established. I have been assured that equipment, papers, photographs, and many other items will be forthcoming when there is a location in which to house these things. Until such a location is established, it would be impossible to determine from where these items would come, and in what amounts they would be contributed. However, without any solicitation on the part of the committee, promises and assurances have been made. Therefore, the question of our being able to get the equipment seems to be the easiest one to answer in the affirmative.

Could the museum project be financed? Although it is difficult for anyone to say whether or not it could be financed without knowing how much it will cost, there is much evidence to indicate that if the project is really worthwhile, it could be financed. I do not believe that any one group within the dental profession could or should assume such a responsibility. However, if all groups that share in the benefits of being associated in the dental profession will assume their proportionate obligation—not only in a financial way but in every other way—this plan will then cease to be an impossibility, and will more nearly reach fruition. It has been estimated that there are somewhere between 125,000 and 150,000 men and women who are depending upon the dental profession for their livelihood. It is inconceivable to think that this large group would fail to respond in a manner consistent with the history of our profession.

The answer to the question of financing the museum cannot be accurately determined on the basis of available information. When further study reveals the method to be adopted in attaining this goal, when the location and type of building have been decided upon, and when we know the cost of the project to the dental profession, we can then survey the possibility of collecting the funds, and then we shall have the answer.

The third question dealing with the possibility of establishing such a museum is: Could we find a suitable location? The answer to this question is very definitely in the affirmative. It is not my purpose in this article to promote any particular type of location for this museum. Some members of the profession think that it might be located on a campus of one of the centrally located universities, where the facilities would be conducive to seminars, clinics, and research, especially for the teaching of all phases of dentistry. Other smaller museums of dentistry throughout the country are already in existence, and one of these could possibly be expanded into a national dental museum. Still another suggestion is the Smithsonian Institution. This institution has for many years been acquiring many of the instruments and appliances which best show the technologic development in dentistry. There are several hundred original U. S. Patent Office models from 1830 to 1880 relating to various dental inventions and discoveries. The Smithsonian Institution has just recently received from the Northwestern University Dental School the complete dental office equipment owned and used by

Dr. G. V. Black (Fig. 1). This equipment is viewed by thousands each year. I know that we all agree that one chair does not tell the story of American dentistry.

The Academy of Denture Prosthetics, the American Denture Society, the Pacific Coast Society of Prosthodontists, and THE JOURNAL OF PROSTHETIC DENTISTRY have been working toward a solution to this "challenge." Because of the fact that collections of equipment and memorabilia of dentistry are being accumulated in a group of small museums throughout the country, it seems that we should try to find a location where as much of this material as possible could be in one building for the greatest use of the largest number of people in dentistry, whether they be professional men or laymen.

Therefore, it is logical to assume that a location can be found for the achievement of this goal.

WHAT IS OUR NEXT STEP?

I am certain that if I were to send letters to my colleagues in the profession, I could, without difficulty, receive pledges of money, assurances of contributions of equipment, and thousands of other pledges of support. However, in my judgment, this would not be a logical procedure to follow at this time.

Because this is such a large project, and because we must move in a logical sequence steadily and relentlessly toward our goal, we must proceed step by step so that a minimum of error will result from our efforts.

It seems to me the next step is quite clear. It is based upon the following points:

1. A strong organization must be established whose sole purpose is to investigate the various ramifications of this proposal.
2. This organization must represent all phases of dentistry, including the dentists, trade associations, laboratories, manufacturers, dental organizations, and educational institutions. All organizations will benefit; therefore, all organizations should be represented. This will tend to minimize the possibility of the development of pressure groups with selfish motives.
3. A Board of Directors should be selected by the various groups comprising the dental family. It has been suggested that fifteen members make up this Board of Directors with three chosen by the trade organization, three by the laboratory interests, three selected by the dental manufacturers, three from educational institutions, and three dentists representing all dental organizations.

As president of the Promotional Committee, which was selected by the organizations mentioned above, I propose to write letters to each of these organizations, asking them to select before Jan. 1, 1957, their representatives for this board.

The duties of this Board of Directors will be fourfold:

1. To determine if we want to accept Dr. House's "challenge" and proceed toward the establishment of a museum.
2. To determine how the museum can be established from the standpoint of cost and availability of equipment.

Fig. 1. (From the Smithsonian Institution.)

3. To determine the best possible location for such a museum from the standpoints of convenience, cost, and other considerations.

4. If the decision of this Board of Directors is to proceed toward the achievement of the museum, then the steps necessary for its establishment must be planned and executed by this Board.

REFERENCE

1. House, M. M.: A Challenge, J. Pros. Den. **2**:434-437, 1952.

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HOW DENTOGENICS INTERPRETS THE PERSONALITY FACTOR

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WHY SHOULD WE BE concerned with the personality of a patient when constructing a denture? Simply because this is our best measure of his priceless individuality, and the most reliable source of knowledge by which we may express his dignity through prosthodontic methods. Personality has been a nebulous term, quite often, but loosely applied to the description of a desired esthetic quality in a finished denture. The complete fulfillment of this quality depends upon a great deal more than its descriptive inclusion in literature. It is not only a good quality, but a necessary quality, if our dentures are going to be as individual as the faces they go into. In our previous discussion of the sex factor,[1] we pointed out that sex identity in dentures (the smile) was dependent upon the personality and age factors for its final execution. The actual simplicity of the basic "male" or "female" tooth form is that it is a refinement of that tooth form which has its inception in the personality factor. Likewise, age is a refinement of the personality factor. Thus the foundation for dentogenic restorations is the personality of the patient.

The comprehensive use of personality depends upon our manipulation of tooth shapes (molds), tooth colors, tooth position, and the matrix (visible denture base) of these teeth. Our orientation to the level of personality consideration in prosthodontics is made easier if we make all other factors incidental to the basic selection and interpretation of patient personality. For instance, as we begin this esthetic procedure, let us not be concerned about tooth outline form as we know it. The outline form of a tooth is *incidental* because it can be controlled by the form we give the matrix of the tooth (Fig. 3). By the manipulation of the interdental papillae, the outline form of a tooth can be established at will, in a matter of seconds. The assistance of a technician skilled in these techniques is invaluable when the plastic interdental papillae must be finished to the exact contour we have so carefully given them in the wax. Incidental, too, is sex identity and the effect of age we impart to the denture.

GIVING PROSTHODONTIC IDENTITY TO PERSONALITY

Over a period of many years, we have tried to find our own simple and practical method of making dentures look natural and pleasing. We desired speed and accuracy with a minimum of failure. The difficulties we had to overcome

This is the third of a series of six articles on Dentogenics in the J. PROS. DEN. (5:586-595 [Sept.] 1955; 6:160-172 [March] 1956).

Received for publication March 12, 1956.

were universal. The obstacles we experienced arose from two sources—and had to be dealt with before our surprisingly simple and accurate esthetic concept could be developed. These two obstacles were "overabstraction" and "oversimplification."

"Overabstractions" in our esthetic endeavors are found to be an intellectual sin used too often in dental literature. Words which are abstract in meaning—yes, even personality—which have no specific and comprehensive identity for dental use should be avoided. We have found no field of prosthodontic endeavor so sadly lacking in simple organization of its working principles, so haphazard or hit and miss, or so hopelessly involved in overabstraction of its terminology as the whole field of dental esthetics. So it could be with the term, personality.

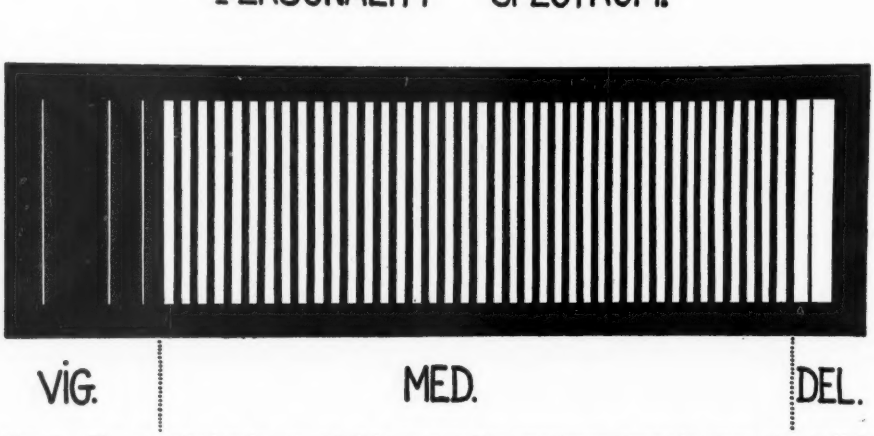


Fig. 1.—The prosthodontic use of this personality spectrum depends upon the individual dentist's ability to visualize the position of his patients within this framework. Most men are found to be toward the vigorous end of the spectrum and most women are found to be toward the delicate end of the spectrum. However, both may still be within the broad medium personality band.

Our own good sense tells us that we can easily be guilty of "overabstraction" in its use, and fall into the useless contemplation of a nebulous term, one which is high-sounding but unspecific for our technical purposes. We avoid this in two ways. Primarily, we deal only with the *objective* physical personality of the patient, and, second, we will keep our discussion of the personality factor specifically within the framework of the "personality spectrum"[2] (Fig. 1). Therefore, we reconcile our use of the otherwise abstract term "personality" by explaining the precise prosthodontic application of this word in the three divisions of the personality spectrum (Fig. 1):

1. *Delicate*—meaning fragile, frail, the opposite of robust.
2. *Medium Pleasing*—meaning normal, moderately robust, healthy and of intelligent appearance.
3. *Vigorous*—meaning the opposite of delicate; hard and aggressive in appearance, the extreme male animal, muscular type, almost primitive, ugly.

Prosthodontic inclusion of personality, in the above sense, together with the sex and age factors, overcomes the other common fault of esthetic endeavor, that

of "oversimplification" of esthetic problems. By "oversimplification," we mean that it has been a common error to attack the esthetic problem on *one* front only. Most of the esthetic procedures used today rest upon, and emphasize, the use of predesigned *materials* for the denture.

Materials *are* esthetically important, but only as far as the paint and canvas are important to the artist. The predesigned denture materials which were conceived for mass-produced esthetics are an example of this "oversimplification." We believe the deadly monotony of the ill-concealed "denture look" is mainly the result of this practice and its prevalent acceptance by dentists. The popularity of "characterized teeth" and "characterized denture bases" and other inviting esthetic terms usually arises from the dentist's sincere desire to do something better esthetically for his patient. Our attack on the esthetic problem must be on two fronts, a sound material concept plus an artistic "know how." The personality factor, when understood and used, guides us in this campaign by exacting both from us.

PERSONALITY AND ARTISTIC "KNOW HOW"

The most sensitive area of expression is primarily in the location of the mouth and is supported by the alveolar processes, the soft tissues covering them, and the teeth. The dentist, therefore, is pretty much in control of the base upon which this expression area functions. He controls the size, the shape, and the comfort of the supporting tissues. The intelligent manipulation of these underlying structures in prosthodontics, together with their pleasing appearance and emotional expression, is rewarding because it maintains a pleasant objective personality, and it contributes to the healthy subjective personality of the patient. Therefore, we can be content to interpret, maintain, and enhance, if possible, the "physical personality" of the individual in this highly expressive area.

In the course of normal social activity, the smile is the *primary objective personality* of a human being. The variety of facial expression or lack of expression is a mirror for people's thoughts, emotions, attitudes, and even the kind of lives they lead. A study of this character and personality reflection easily identifies the individual in the personality spectrum as either vigorous, medium pleasing, or delicate. The smile and the whole orofacial area become vacuous and monotonous by the exclusion of this individuality from our esthetic procedure. Mere sex identity could not possibly complete our requirements for a dentogenic restoration as we come to comprehend the reason for the differences in feelings and appearances. We wonder how popular television and movies or even magazines would be if all people were reduced to one male and one female type. So, regardless of whether this face and figure of ours are our fame and fortune, Nature has endowed us with something far more important, the dignity and satisfaction of being an individual with a personality of our own. Neither we nor our patients wish to have this individuality overlooked in the primary objective personality center, the smile. The personality spectrum can be used in our artistic endeavor to inject a variety of tooth form and tooth position, at the comprehensive level of individual patient personality analysis.

THE USE OF THE PERSONALITY FACTOR

Dentogenics includes the *combined* sex, personality, and age interpretations. These factors are inseparable and interdependent. Only when they are fused in the final denture is that particular restoration eminently suitable in that, for the wearer, the denture adds to that person's charm, character, dignity, or beauty in a fully expressive smile. If this is our esthetic goal in complete denture work, then we must consider none of these factors as being separate or independent, and when we incorporate the *personality* factor in esthetics, we do so keeping in mind the influence of the sex and age factors as we proceed.

It was apparent to us from the beginning that to embrace wholly any one factor, such as sex identity, would only lead to a denture look of a new kind. The avoidance of this common fault led to the prosthodontic development of the personality factor, and further to the personality spectrum by which we achieved a usable measure of the objective personality of any given patient. This is a measure by which we can transpose the "personality" information to the fabrication of the denture itself, and thence to the smile. Comprehensive use of the patient's personality becomes practical only if we limit the personality spectrum to the extremes of vigorous and delicate. As is shown in Fig. 1, the broad area between the extremes can be composed of so many variables that we feel safe in the maintenance of *individuality* in our esthetic result, and thus avoid a repetitive pattern. A small percentage of patients are delicate, and a slightly larger percentage are vigorous. The remaining majority of patients fall into the medium section of the personality spectrum, but all of these have either vigorous or delicate tendencies. For instance, most vigorous patients are men, and most delicate patients are women. However, it is quite possible for a woman to have personality traits described as vigorous and a man to have personality traits described as delicate. Here we come to appreciate the full power of the personality factor, because if this did not appear in our prosthodontic experiences, the personality spectrum would have little value except to identify men as vigorous and women as delicate, with slight variations thereof.

Throughout the years, the comprehensive predetermination of esthetic results has been a fascinating thought. Something in lieu of the "trial and error" method of repeated try-ins seems to be a very desirable goal. Through the personality spectrum the keen edge of our imaginative perception and its practical use takes form.

PERSONALITY AND MOLD CONSIDERATION

The esthetic orientation we undergo, when approaching the esthetic problems of prosthodontics by the use of the dentogenic concept, is less trying and confusing when we consider the smile as the *primary* objective personality trait of the patient. We use this primary objective personality trait and the personality spectrum for the selection of a *mold category* of the artificial teeth which we intend to place in that patient's denture. Therefore, when we approach the problem of selecting a mold category, our first analysis is of the patient according to his position in the spectrum. This is the first step to the consideration of a mold category and *not* the exact mold selection per se. The term "mold selection" is

dangerous in that it implies a finality which is impossible. Since there will never be enough molds available to correctly fulfill the requirements of prosthodontics, the dentist must compensate for the limited variety of shapes of artificial teeth at his disposal, and use a comprehensive method of achieving refinements of these molds in order to reach a true reflection of the patient's individuality. The authenticity of patient personality and the implication of the personality spectrum in our esthetic interpretation transcend the necessity for commercial material consideration. The truly great prosthodontist could create molds identifiable in the personality spectrum, that is, a new mold for each patient. Wilhelm Zech has given us his concepts of the molds in the personality spectrum in vigorous, medium, and delicate categories. He regards his own creations, however, as merely fundamental shapes which must be subjected to the refining procedure of

Fig. 2.—*A*, The type of central and lateral incisors and cuspid which would be used for the youthful, good-looking "model" type of patient. Because of their idealism, these teeth are indicated mostly for women. *B*, These central incisors are considerably more "coarse" and would be adaptable to the ample-bodied, obese woman. *C*, The typical robust form of sculpturing in these central incisors makes them universally adaptable for either men or women by *further shaping*. (See Fig. 3.)

sex and age modifications. Technicians skilled in this procedure, and familiarized with the refinements of sex and age application, by further shaping and grinding according to the dentist's prescription, are a tremendous help in completing a dentogenic restoration. In any event, whether we create our molds or whether we select a mold category already manufactured for us, we should remember that there are few examples of extreme personalities according to our personality spectrum. Only about 10 per cent of our patients will be identifiable as truly vigorous, and only about 5 per cent of our patients will be identifiable as truly delicate, the great majority of our patients falling into the medium part of the personality spectrum. The great majority of molds will be those from the medium pleasing personality category (Fig. 2).

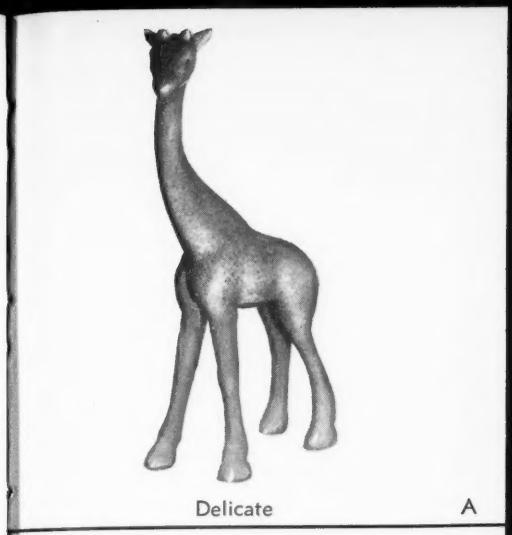
Naturally, the central incisors of any selected mold can be ground to shorten or narrow the teeth to the required proportion. The grinding of the lateral incisors

Fig. 3.

Fig. 4.

Fig. 3.—A treatment of the tooth mold seen in Fig. 2, *C*. The teeth on the left have been shaped to appear soft; on the right they have been shaped to appear hard. The outline form of the teeth is easily changed by manipulation of the matrix as well as by grinding.

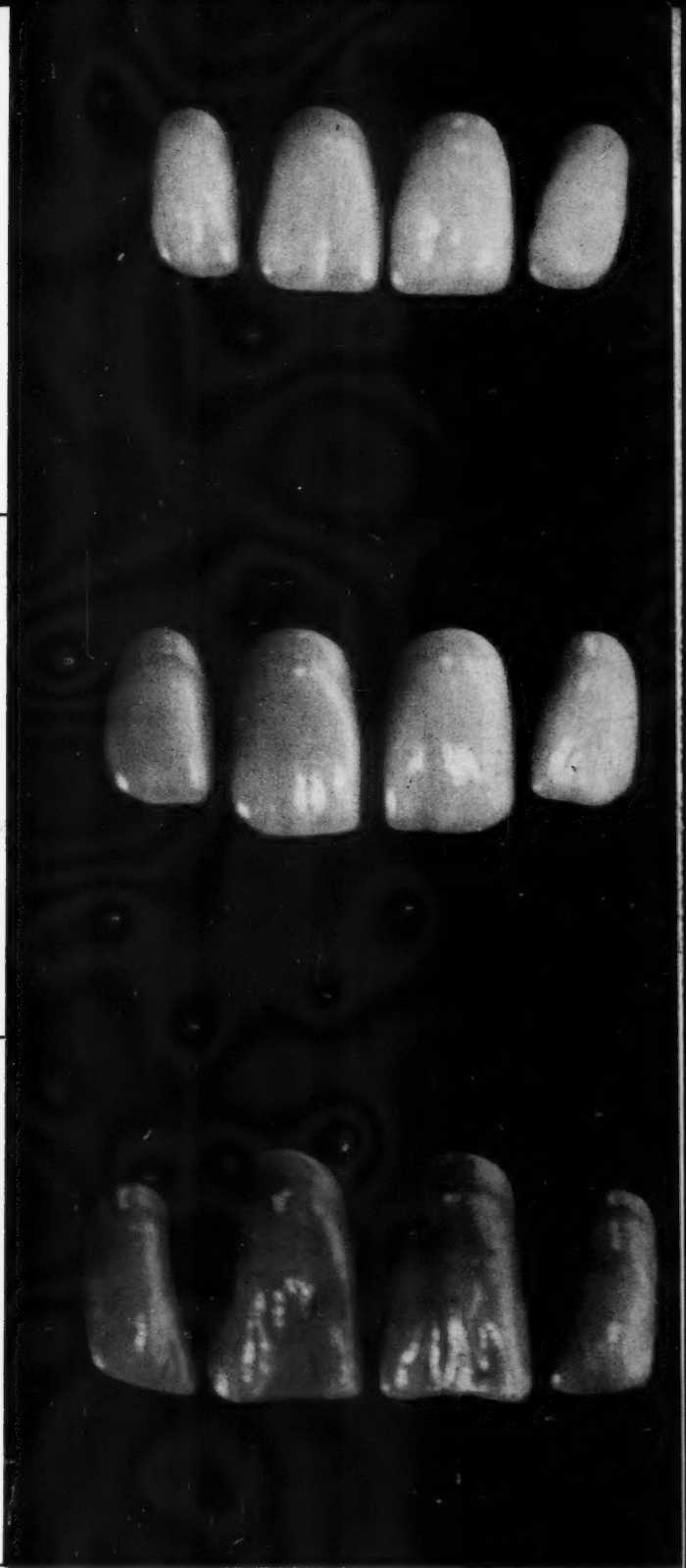
Fig. 4.—The effect of age is added to tooth form by the abrasion of the incisal edges, the use of diastemas, gingival erosion, and the manipulation of the interdental papillae.



Delicate A

Medium B

Vigorous C



A. Note the delicate contours of the sculptured giraffe and the same delicate contours of these teeth.

B. Note the medium character or personality in the sculptured llama and the same medium pleasing character of these teeth.

C. Note the vigorous type of sculpturing as represented by the bull and the teeth of the same vigorous quality.

Fig. 5

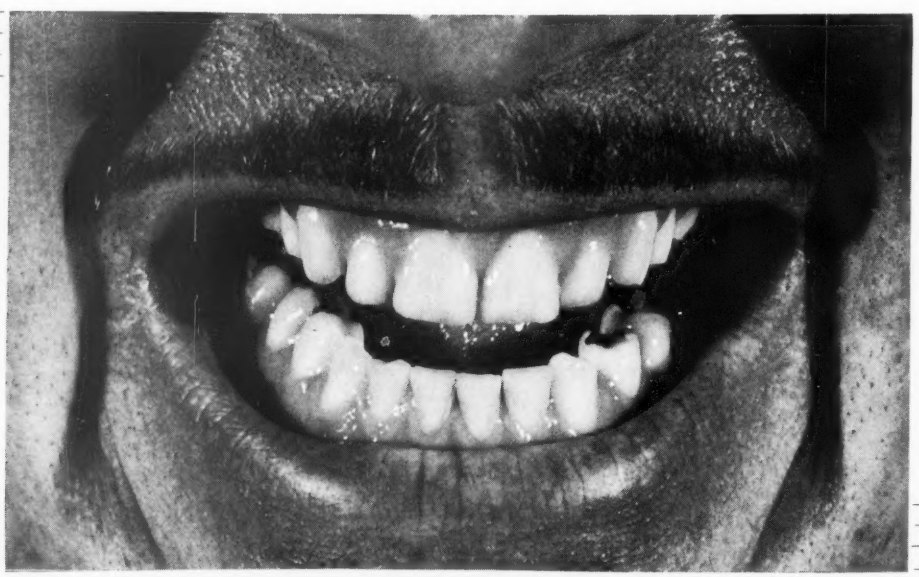
A. Lack of artistic overaccentuation in either color texture or form lends to monotony and denture look.

B. Overaccentuation of color texture and surface anatomy is harmonious with the vigorous personality expressed in the denture (6-D) for the aggressive, hard mouth (6-E).

C. Common, "minus" overaccentuation.

D. "Plus" overaccentuation, appears harsh when seen out of the mouth, proper in the mouth (E).

E



E. Vigorous treatment of the teeth, their position and their matrix, for a vigorous patient blends correctly when the personality of the patient is used as a guide in this denture.

Fig. 6

and cuspids is not usually required if any change in the *proportion* of the central incisors is to be made. Outline form, as such, in the initial mold selection or in the refinement of the mold selected is incidental because it is controlled by the manipulation of the interdental papillae, both in the wax and the finished plastic denture base (Fig. 3). Further refinement is accomplished by the incorporation of the sex factor,[1] by curving the incisal edges of the central and lateral incisors for women and squaring the incisal edges for men (Fig. 3). This achieves a general spherical and cuboidal effect, respectively. The last refinement of the selected mold is the incorporation of the age factor by simulating erosion, abrasion, diastemas, et cetera, (Fig. 4) in the central incisor, lateral incisor, cuspid, and bicuspid teeth. All of these refinements are done with the personality spectrum as the basis on which the mold category is chosen.

ARTIFICIAL TEETH AND PERSONALITY INTERPRETATION

Our illustrations of the analogy between sculptured artistry in animals and the sculptured effect possible in artificial teeth (Fig. 5) is elementary. Please do not construe our examples of sculptured animals to be anything but a symbolism. We realize that no one looks like a giraffe, a llama, or a bull, and the use of pictures of these animals is only to demonstrate the artistic ability of sculptors in their interpretation of varied character.

In transferring our personality analysis of the individual to the artificial teeth, we can take a lesson from the sculptor who formed the frail, delicate qualities we see in the giraffe (Fig. 5, *A*). By applying these same principles of sculpturing to the form of a tooth, we have the opportunity of selecting or creating a tooth which portrays a delicate, frail type of personality.

By selecting a mold of the delicate category, and using it in the mouth of a frail, delicate person, we retain a harmony between the personality of the artificial tooth and the personality of the individual. This corrects the static denture look, and gives each dentist an effective tool for individual artistic expression.

In the figure of the llama less delicacy is apparent (Fig. 5, *B*). It portrays more detail and more interpretation of the medium pleasing personality or character in sculpturing, and likewise, less frailty. A truly sculptured tooth of the medium pleasing category expresses a similar medium personality or character when viewed in the mouth. Such a tooth is seen as robust and pleasing, and of a medium type of personality as expressed in the personality spectrum.

As we proceed through the personality spectrum, we approach the opposite limit of the prosthodontic personality interpretation in the form of a very vigorous type of sculpturing (Fig. 5, *C*). Here we see vigor, strength, and aggressiveness; we see the extreme vigorous physical personality. By using the same artistic principles, a sculptor has given us an example of a tooth which, when used in the mouth of a very vigorous person, gives us a harmony which we could never achieve otherwise.

OVERCHARACTERIZATION AND PERSONALITY

By overcharacterization, we mean an overaccentuation of the form, color, and arrangement of artificial teeth as compared with the average concept of an artificial tooth and artificial tooth arrangement. Overcharacterization is artistically necessary because we are forced to use artificial media to create the illusion of reality. We are placed in the same position as that of the artist who attempts to create his illusions of reality on a canvas with his paints: paints which have not the slightest relation to the sky, grass, water, or living tissue he is interpreting, with the exception of color identity. Since we use artificial media to create our illusion of reality in the smile, we find good use also for many of the artist's devices, and particularly the rule of color intensity used in the creation of perspective. For example, what we experience as an ugly overaccentuation of color texture in the artificial tooth (Fig. 6, *B*), when seen in the hand, does not appear as such in the mouth (Fig. 6, *E*). Master ceramists have used this principle to a remarkable degree (Fig. 6, *D*). The harsh overaccentuation which we may notice outside of the mouth seems to lose its intensity, and attains a pleasant harmony in its new environment in the mouth. The same is true of overaccentuation of surface anatomy to produce personality identification of mold categories. The effectiveness of personality in molds of artificial teeth may be seen in Fig. 6, *B*. This is also true in overaccentuation of the tooth position in the artificial denture (Fig. 6, *D*). It is for this reason that esthetic evaluation of artificial teeth, their form, color, and positions in the artificial denture cannot possibly be made until the denture is in its proper environment, the mouth (Fig. 6, *E*). Overaccentuation of form, color, and position is also important in age and sex interpretations. By the same token we keep our concept of overaccentuation within the confines or framework of the sex, personality, and age factors. To proceed in overaccentuation without purpose and without an eye toward predetermined esthetic results would often result in ugliness and disharmony. The artistic license of overaccentuation in tooth form, color, and position is, therefore, not a reproduction or copy of nature. We should not reproduce those undesirable features of a dentition which are produced in nature. Rather, we should make an artistic prosthodontic interpretation of the sex, personality, and age as dictated by the needs of each patient, regardless of the size, color, shape, and position of the natural teeth. Artistic errors of nature should not be repeated.

PERFORMANCE OF INDIVIDUAL TEETH IN PERSONALITY INTERPRETATION

In our dentogenic procedure, the mouth is like a stage, and the teeth are like the actors on this stage. By this analogy we realize that each tooth is responsible for its *individual* performance and gives the proper effect in the mouth according to the theme selected for it in our interpretation. Just as overaccentuation of make-up on the actor's face disappears in the environment of the stage, so does the overaccentuation of form and color in the artificial tooth disappear and become harmonious when it reaches the mouth. Even the movement of the actor on the stage, although overdone, appears natural and expressive, whereas the same movements in our own drawing room would appear affected and unfitting. Thus it is

with overaccentuation of tooth position, in placing emphasis upon various phases of the personality. In dentogenics, therefore, the concept of the position of the six anterior teeth as a group is not used. Instead, each tooth is treated as an individual in form and position to produce independent personality effects in the patient's mouth. Just as various actors on the stage have their parts to play, so do each of the visible teeth in the smile. For instance, the central incisors being in the center and front of the stage, play the leading role. Their overaccentuation contributes the desired strength and action of the smile. The lateral incisors, being subordinated in position to the central incisors, are the supporting actors on the stage and convey the hardness or softness, the aggressiveness or the submissiveness, the vigorous tendency or the delicate tendency of the patient in the personality spectrum. The cuspids must dominate the lateral incisors in color, form, and position, and their treatment conveys either a strong, pleasant, modern accent or an ugly primitive accent to the smile. The playwright has the power to conceive his theme and project its meaning through the medium of actors playing their individual parts. Likewise, the dentist has the possibility of conceiving his own esthetic theme for that smile, with consideration for the individuality and personality of his patient, and projecting it in the smile. Since the dental arch is visible from molar to molar in an expressive smile, the bicuspids are esthetically important. They must achieve individuality through variations of their long axes, and through variations of their color. It is extremely effective to vary the shades of the bicuspid and molar teeth, sometimes rather severely.

SUMMARY

1. Personality is a practical and inspiring approach to primary mold selection. It paves the path for the further sex and age refinements which are necessary to the dentogenic restoration.

2. The consideration of the personality factor allows a realistic approach to the problem posed by the necessity of using artificial substances to create an illusion of reality in the smile.

3. The personality factor has been shown to be one that can be employed specifically for the predetermination of esthetic results and can help to eliminate the costly and unsatisfactory "trial and error" procedure for obtaining acceptable esthetic results. The personality factor has been interpreted and suggestions for its practical application have been described.

4. The dentist is the artist whose accomplishments in dentogenics are limited only by the degree of skill he has acquired.

REFERENCES

1. Frush, John P., and Fisher, Roland D.: How Dentogenic Restorations Interpret the Sex Factor, J. Pros. Den. **6**:160-172, 1956.
2. Frush, John P., and Fisher, Roland D.: Introduction to Dentogenic Restorations, J. Pros. Den. **5**:586-595, 1955.

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AGING CHANGES AND THE COMPLETE LOWER DENTURE

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FURTHER INQUIRY INTO relevant biology must lead to some resolution of the problem of the complete lower denture. Too often the writers of textbooks on the subject of complete dentures have been perfectly satisfied to describe the muscles of mastication and the anatomy of the maxillae and mandible in the belief that they have provided adequate biologic background. I contend that facial muscles have equal importance in complete denture work. However, the purpose of this article is to focus attention on a changing concept of the anatomy with aging, rather than criticize the contribution of others.

THE CHANGING ANATOMY AND PHYSIOLOGY

Too static a view is often taken of the form of the parts and the way they work; both are constantly changing, from childhood to old age. Metabolism comprises anabolic and catabolic processes; in childhood and youth building processes are in the ascendancy, but with aging, catabolism becomes predominant and atrophies result.

It is well to consider the changes in the anatomy under three headings: (1) the mucosa and submucosa, (2) the musculature, and (3) the bone.

1. *The Mucosa and Submucosa.*—In common with all other tissues, the oral epithelium shows a reduction in the number of its component cells as age atrophy progresses. The mucosa in general, and that covering the mandibular residual ridge in particular, shows a decrease in thickness.[1-8] There are also associated atrophy and thinning of the submucosa, so that the depth of the soft tissue which covers the alveolar ridge is reduced. This change is partly explained by a general dehydration which is observed in old age. It is not noted to the same degree in all patients, and many instances can be called to mind where an old person has shown a substantially thick mucosa and submucosa, giving the palpatory sensation of resilience over the residual ridge. This change in nature of the oral epithelium sometimes reflects similar changes in the skin of the face. The skin of the old is often described as showing many wrinkles as a result of the atrophy of the underlying fatty tissues and muscles. Such a skin as depicted in Fig. 1 is often seen, but so also is a skin of thinner texture having a taut, smoother appearance (Fig. 2).

Received for publication, Dec. 1, 1955.

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In addition to a thinning of the oral mucosa with aging, there is also a reduction in its surface area. This observation results from noting clinical appearances rather than accurate measurement, but when it is considered that the ridges become resorbed the truth of this statement becomes obvious. A less obvious and less constant change is a reduction in the degree of invagination of the cheek tissues toward the oral cavity. Sometimes too, the secondary undulations of the buccal mucosa become less marked. Both of these effects contribute to a reduction in surface area of the oral mucosa (Fig. 3). Further, if there is any associated approximation of the jaws (and this is disputed[1, 4, 5, 6]), this will also have a similar result. The outcome of these changes, which may be present to a greater or lesser degree, is a reversion to a more circular form of the oral cavity, and it might even seem as if the highly differentiated mucosa is seeking to economize in area.

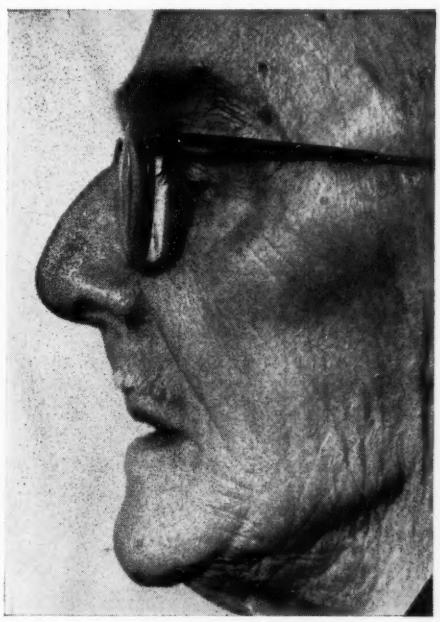


Fig. 1.

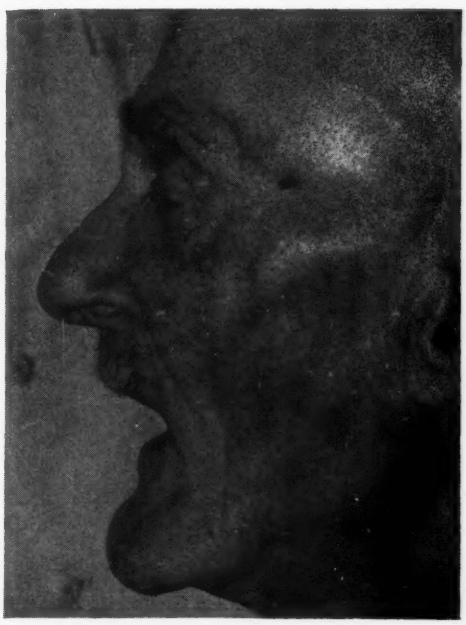


Fig. 2.

Fig. 1.—The wrinkled type of skin in an old person.
Fig. 2.—The taut, smoother type of skin in an old person. The mouth is slightly open to show the inversion of the lower lip.

The form in sagittal rather than coronal section also seems to substantiate this viewpoint. In the retromolar area, the rounded form of the mucosa as it sweeps from the edentulous ridge to the ramus of the mandible is often observed in association with vertical tissue folds. A backward movement of the lip, to be discussed later, also has the same effect.

This potentiality to reduce surface area of the oral cavity is variable. So also is the surgeon's ability to maintain an epithelial inlay cavity surgically created for the retention of a complete lower denture. Some of these are well preserved and function effectively in stabilizing the denture; others tend to become quickly

obliterated, the explanation given being that they have "fibrosed up." An alternative or additional explanation might lie in the relative tendency of the mucosa to establish a reduced surface area.

As well as these macroscopic changes in the aging oral mucosa, one important microscopic change is of practical importance. In the skin, there is a degenerative change in the elastic fibers, and a condensation and aggregation of them into irregular masses.[7] An associated biochemical change of a controversial nature takes place in these fibers.[8] In a series of twelve histologic sections taken from the cheek and mucosal reflections of young and of old individuals, similar changes to these noted by Dick[7] were seen in the latter group (Fig. 4).

The net result of the changes in the form of the oral mucosa, and in its elastic fibers, is a decrease in its elastic quality, an end result which has been noted by Burket,[9] Goldman,[10] and Massler.[2]

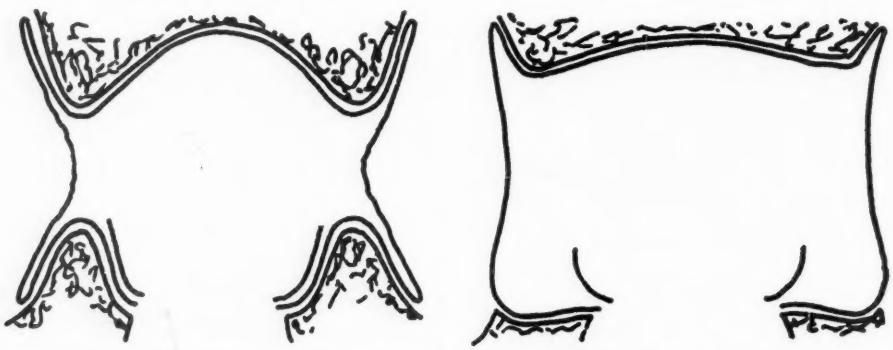
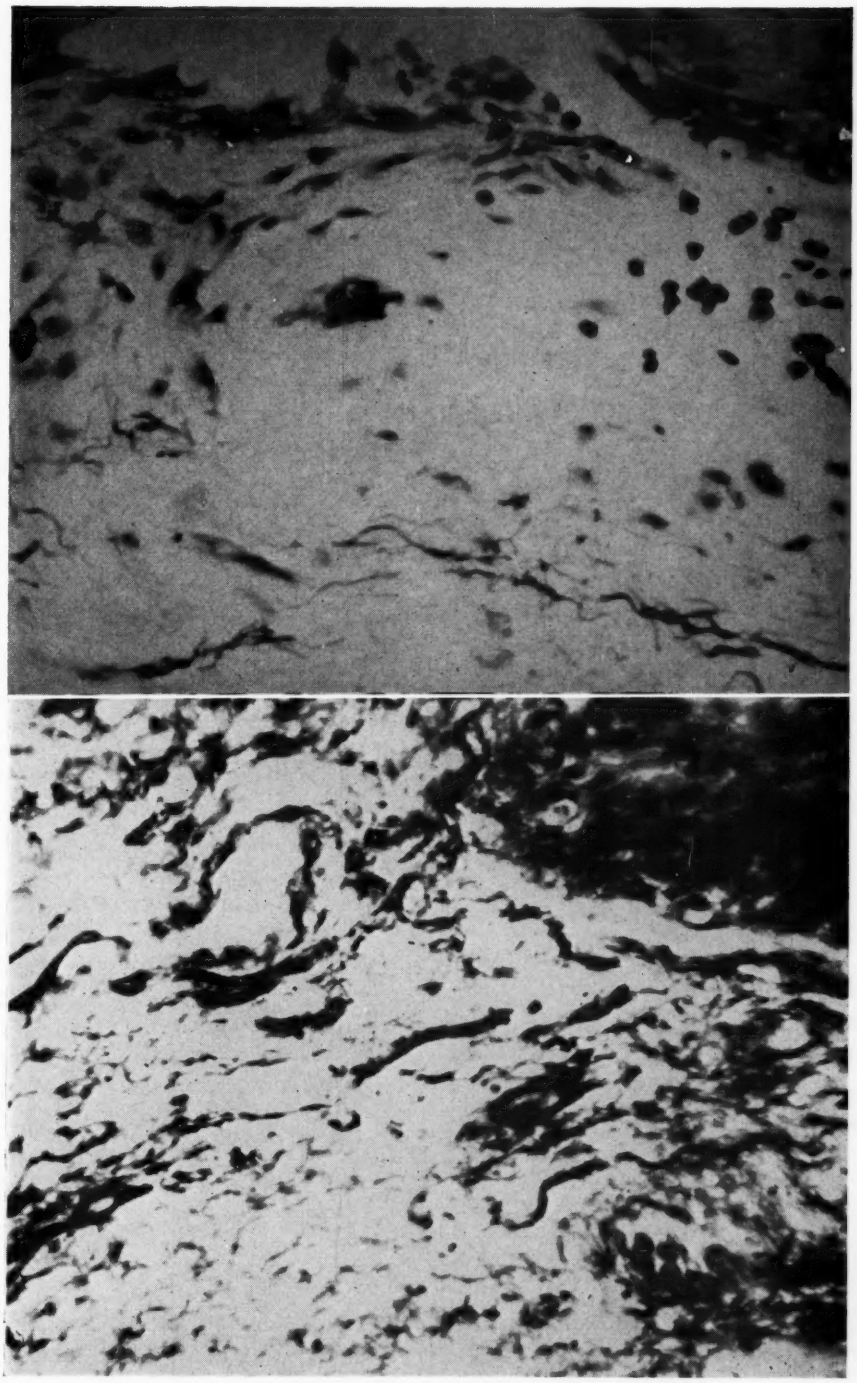


Fig. 3.—Diagrammatic representation of the reduction in area of oral mucosa which takes place with aging. The coronal section of a young edentulous adult is shown on the left and of an older individual on the right.

2. *The Musculature.*—Gabel[11] described a migration of the origin of the buccinator fibers over the buccal plate of the mandible toward the midline, and emphasized the effect this has on reducing the neutral zone. An even more important change in muscle origin concerns the mentalis muscles. These muscles take origin bilaterally from a circular area on the alveolar ridge and body of the mandible above the mental tuberosity. The highest point of origin lies superior to the position of the mucosal reflection when the natural teeth are standing, and over the roots of the lateral incisor and canine teeth. The fibers of this muscle diverge medially and laterally to be inserted into the skin of the chin, and also superiorly and inferiorly so that some are inserted into the lower lip.[12] When resorption of the residual ridge and body of the mandible takes place, the level of the ridge crest falls below that of the former origin of the superior fibers of the mentalis muscle. In order to maintain its area of origin, the muscle attachment folds over the resorbing alveolar ridge and comes to lie on the superior surface of the residual ridge. The result of this is a backward movement, and some reduction, of the neutral zone in the anterior part of the mouth. This change in the origin of the mentalis muscle has been observed in the surgical dissections of Mr. J. S. H. Collinge of Liverpool, and from preparations in the cadaver (Fig. 5).

A.



B.

Fig. 4.—Photomicrographs stained with orcein, showing (*A*) the nature of the elastic fibers in the cheek mucosa of a patient aged between 40 and 50 years, and (*B*) the change in form in a patient of 70 years. (X525; reduced 1/6 off.)

At this stage it is pertinent to consider the lower lip form in old and young people who have been rendered edentulous. In a young person, the lower lip form changes very little after all the teeth have been extracted. In fact, if the rest position is induced with the upper and lower lips making a light contact, it cannot be discerned from appearance that the teeth have been lost (Fig. 6). The fullness of the lip and its everted position are maintained, as is also the labiomental angle. The dry red lip margin shows to a normal extent. In cases of age atrophy a marked change is noted. The lip becomes thinner and inclines backward into the oral cavity, the labiomental angle disappearing (Fig. 2). The

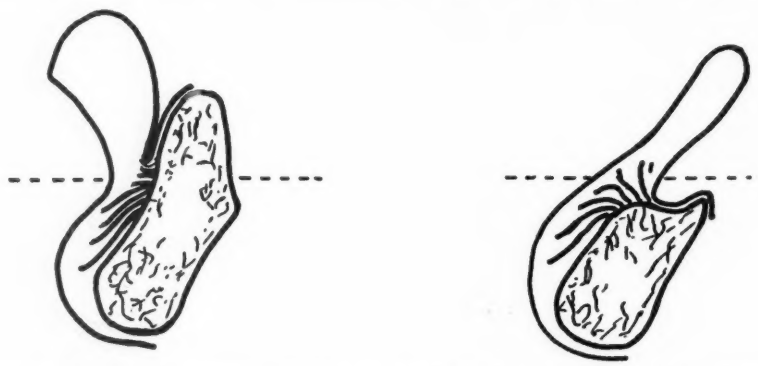


Fig. 5.—A diagrammatic representation of the change in position of the origin of the mentalis muscle seen after ridge resorption. On the left the ridge is well preserved, whereas on the right it has suffered severe resorption.

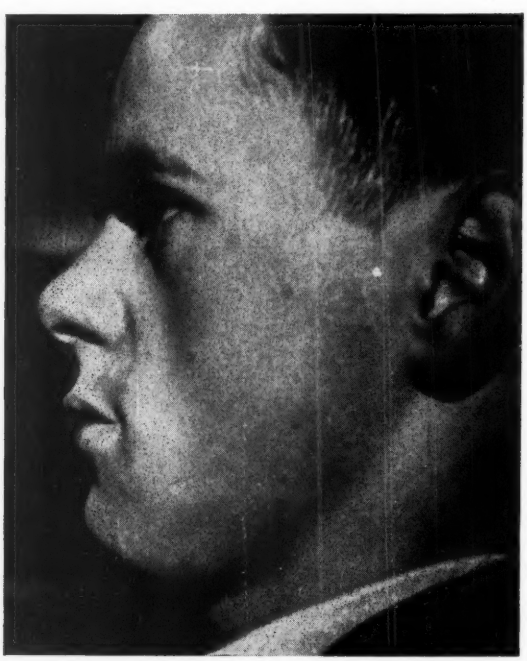


Fig. 6.—The profile view of a young edentulous adult. It is impossible to discern the patient's edentulous state.

amount of the visible red lip margin is now reduced to a thin straight line. The oral aperture between the upper and lower lips seems to become smaller and to move back; a few patients have commented on the narrowing of the mouth, but usually the slow change is not noticed. This change in lip form is due to the more vertical line of action of the superior fibers of the mentalis muscle, and to a reduction in the surface area of the lip mucosa and skin.

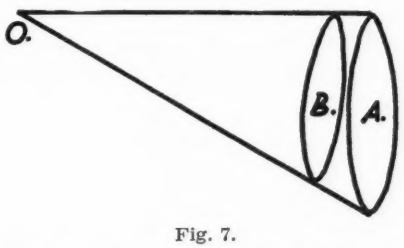


Fig. 7.

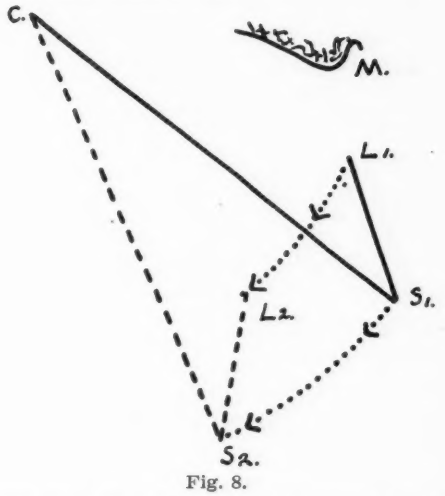


Fig. 8.

Fig. 7.—The lips being no longer able to open to their original circumference *A*, when opening about a hinge axis *O*, they must move back to accommodate to a decreased circumference *B*.

Fig. 8.—Diagrammatic representation of the relative positions of the maxillae (*M*), the atrophic lower lip margin (L_1 and L_2), and the symphysis menti (S_1 and S_2), when the mouth is at rest and fully opened. Although the free lip margin moves back in relation to the maxillae, it moves forward in relation to the symphysis and the degree of lip invagination observed is thus decreased.

Not only is a difference in the form of the lower lip noted when the mandible assumes the rest position; on opening the mouth, the young and the atrophic lips behave differently. In the former, the lip remains everted and the only noticeable change of mouth form is that the corners move together to make the oral aperture circular. The atrophic lower lip, being less elastic, moves slightly inward in relation to the fixed maxillae when the mouth opens to its widest extent (Fig. 7). In this position, it has a vertical or slightly invaginated appearance. It might be expected that the degree of inward angulation should increase. However, it must be appreciated that the symphysis menti is moving backward to a greater degree, giving the appearance of a relative lip eversion (Fig. 8).

3. *The Bone.*—Examination of dried specimens of edentulous mandibles, surgical dissections, and roentgenograms, reveals that cortical bone is often not present in the anterior segment of the residual ridge after healing of the extraction wounds. Noncortical bone is present over the ridge crest in this area. Roentgenograms reveal a typical picture of cancellous bone, showing vertically running nutrient canals. Such a surface cannot be so smooth as one of a cortical nature, and it is made up of the ends of vertically running trabeculae. Sometimes, too, a spicular reaction is noted; the appearance of small spicules of bone or osteophytes accentuates the rough nature of the bone of the anterior ridge.

The second important characteristic of the mandibular ridge is its potentiality for resorption. There can be little doubt that the application of forces in the pathologic range can cause an osteolysis. This type of reaction is often associated with a deposition of fibrous tissue within the submucosa. The osteolysis of the anterior ridge bone beneath a complete upper denture with porcelain teeth worn against only six natural lower anterior teeth is an example in this class. Fibrous tissue replaces the bone, but the mucosa does not retract markedly. Instead it substantially maintains its original form. Sometimes an entire maxillary arch is seen to be very resilient on palpation, indicating a replacement of alveolar bone by fibrous tissue without a marked decrease in ridge height. In the mandible too, the presence of a mushroom-shaped fibrous submucosa which covers a "knife-edge" ridge may be a reaction of this nature. In terms of Wolff's Law,[13] the reduction in the number of the bony trabeculae and even their final disappearance are reasonable, but this process cannot account for a change in the form of the ridge bone and the eventual loss of the ridges. Nor is it sufficient to account for the disappearance of the ridges by saying "the teeth are lost; the ridges are redundant and disappear." Cases of anodontia are seen where ridges are present. The change in ridge form implies the presence of some molding force, the nature of which can be determined only as a result of a long-term research project undertaken by scientists with special knowledge in different fields. The possibility of that force being an atrophying mucosa seeking a reduced area must be borne in mind. Very often flat lower ridges are seen where no dentures have been worn previously, and thus the possibility of denture trauma being causal is excluded; it is significant that in such cases the lower ridge is always covered by a thin, tightly stretched mucous membrane. This is also true of a resorbed ridge seen where the lower molar teeth have been extracted and only premolars and anterior teeth remain. If in such a case the ridge is well formed, it is covered by a thick, keratinized mucosa.

Most authorities on periodontal disease recognize a condition described by Stones[14] as senile gingival recession. The epithelial attachment is no longer located at the amelocemental junction, but is attached entirely to the cementum, sometimes at a distance considerably apical to the enamel margin. A reduction in surface area of the mucosa with associated loss of alveolar bone may be partly causal. Thus it is possible that the same factors which cause senile gingival recession also cause alveolar resorption.

This hypothesis does not disregard the well-known effects of function on the oral mucosa, nor does it assume prior importance over recognized factors which act on bone directly. Important among these latter are the presence of periodontal disease prior to extraction, the action of hormones, and pressure. It also recognizes an inherent bone factor offering greater or less resistance to molding pressure. In general, a dense cortical bone, or a heavily trabeculated noncortical bone offers high resistance. Sometimes a well-formed upper ridge and palate are seen to be covered by a thin, taut, mucosa; here the highly calcified bone is very stable in form. On the other hand, the osteoporosis and negative calcium balance in the aged are conditions resulting in a plastic bone structure liable to be affected by small molding forces. This factor acts locally in the same individual,

as well as generally in different individuals and races. Dense bone in the area of muscle attachments and zones subjected to concentration of stress exemplifies areas offering high resistance to change of form. Thus, in the mandible, this accounts for the unchanged position of the superior genial tubercles to which the genioglossus muscles are attached; these are often seen posterior to a resorbed anterior ridge forming a hard prominence in the floor of the mouth, and present a problem in denture technique. A sharp superficial bony ridge underlying a thin mucosa is sometimes seen posteriorly and bucally, remaining relatively unresorbed above a concave, resolved, residual ridge; this is the external oblique ridge which is a heavy cortical reinforcement that resists a concentration of stress. A similarly placed ridge, the mylohyoid ridge, lies lingually and also resists reduction.

Finally, it is pertinent to consider the atrophy seen at the climacteric. Every prosthodontist has observed the rapid reduction in the height of the mandibular residual ridge which is sometimes seen at this period, characterized by a hormonal imbalance and especially a reduced estrogen blood level.[15] A postmenopausal osteoporosis results in a bone offering little resistance to reduction in volume.[16] Albright and associates note an association between this condition and a tendency to atrophy of the skin. Also the effect of the reduced estrogen level in producing an atrophic oral mucosa has been noted. The rapid loss of the residual ridge after the menopause is accounted for in terms of an atrophic mucosa molding a weak bone structure.

THE APPLICATION OF THESE OBSERVATIONS

It is pertinent to consider the application of these observations to a complete lower denture technique, bearing in mind the fitting surface, the border, the polished and occlusal surfaces of the denture.

1. *The Fitting Surface.*—One point which has emerged from extensive clinical trials is the need for developing an adequate soft denture base. The great advantage of a soft denture base is seen in cases where atrophy of the mucosa and submucosa is marked. The thin soft tissues cannot absorb any of the energy applied through the denture when the upper and lower teeth occlude forcibly, since there is little tissue fluid which may be directed into different tissue planes. Further, the potentiality of a resilient tissue layer for distributing the load evenly over the spicular bone of the anterior region does not exist. In these cases, nerve endings overlying the bony trabeculae are stimulated by pressure from the hard denture base, and pain is the inevitable outcome. A reasonable approach would be to replace, on the denture, the resilient layer which previously existed in the tissues covering the ridge bone. The compression of this layer, as well as absorbing some energy, also aids in the even distribution of force over the spicular bone. Patients who show this atrophy of mucosa and submucosa generally obtain complete relief of pain after a soft denture lining is substituted.

2. *The Border.*—It is necessary to define and to discuss the significance of four positions of the vestibular sulcus: (i) resting position, (ii) functional position, (iii) compressed position, (iv) distorted position.

(i) *The resting position:* At no time does a space exist between the mucosa of the lip and the cheek on the one hand and that of the lower alveolar ridge on the other. The potentiality, however, exists for the accommodation of a denture flange between the two mucosal surfaces. This potentiality has a definite limit which depends on the depth of the resilient submucous layer in the lip and cheek, and also on the muscle tone.

The resting form of the mucosal reflection is its most important position, in that the greatest possible length of the reflection should finally be represented in this state on the working cast. Further, if any modification of the sulcus form is considered desirable, it should be made from the rest position as a starting point.

The resting position of the sulcus is its unstrained form when the jaws are in the rest position. However, since in many cases, on opening the mouth slightly, there is little *practical* change in its form, the resting form of the vestibule may be recorded by an open mouth impression technique.

The resting position of the floor of the mouth should now be considered. With the jaws in the resting state, the dorsum of the tongue contacts the hard palate, and its tip lies in contact with the lingual surfaces of the lower anterior teeth. This tongue position is maintained with the floor of the mouth in a corresponding resting position, and it is this which governs the resting depth of the mandibular alveolar ridge lingually. On opening the mouth, the tongue falls back to maintain a contact with the pillars of the fauces and the soft palate to seal the entrance to the oropharynx. With the tongue in this position the floor of the mouth is lowered, giving a false depth to the lingual side of the alveolar ridge, especially posteriorly. Therefore, if an open mouth impression technique is preferred to a closed mouth procedure, the tongue must be placed with its tip lightly pressing against the tray handle; it is necessary to instruct the patient how to effect this compensatory tongue movement, placing the floor of the mouth in a resting position.

(ii) *The functional position:* The form of the reflection of the vestibular sulcus is changed as a result of: (a) opening the mouth, (b) local muscle contraction.

(a) Opening the mouth: On opening the mouth, the sulcus form changes by becoming less deep and more angular; the mucosa is more tightly stretched and less able to withstand displacement without developing a force of reaction.

In young adult life and when the mucosal tissue displays a good elastic quality, the change in sulcus form on opening the mouth is not of practical importance in complete denture prosthetics. In an atrophic condition where the elastic quality is reduced, a significant change in the sulcus is more likely to occur, and this may be sufficient to effect a displacing force on the border of a denture, especially during the widest opening (Fig. 9). Accordingly in this atrophied state, the denture is extended only to the functional position of the sulcus, and a sharper rather than a rounded denture border form is favored; this permits the obliteration of a potential space below the denture border when the mouth is closed, as the buccal mucous membrane is allowed to collapse against the alveolar plate. In this way retention is improved at the expense of denture strength.

Roughly assuming a line between the condyles to be a rotatory axis when the mouth is opened, we can account for the observation that progressively greater separation of upper and lower teeth takes place in the anterior part of the mouth. This explains the fact that the change in shape of the sulcus is noted to a greater extent in the premolar than in the molar regions. In the most anterior part of the mouth, the change is not so marked, as the opening is compensated for by the separation of the free upper and lower lip margins.

Thus when making an impression for a patient showing marked atrophy of the mucosa, an open mouth technique is preferred. The degree of opening used should be within functional limits rather than to the widest amount.

Fig. 9.—A diagrammatic representation of the potential change in sulcus form taking place on the widest opening in a patient with an atrophic oral mucosa.

(b) Local muscle contraction: The sulcus form may be altered by muscle fibers which run vertically or obliquely to the direction of the reflection. The variable degree to which this takes place depends upon the habit of the patient, the degree of muscular development, and the closeness of the muscle insertion to the mucosal reflection. In the lower labial and premolar regions this change may be considerable, and a functional position of the periphery is indicated. Once again a sharp rather than rounded denture border helps to maintain a positive retention.

Fortunately, very few patients show this excessive range of muscular movement functionally. However, it is important to recognize such a patient when he presents himself requiring a complete lower denture. He is usually of a nervous disposition, engages in facial gesticulation when conversing, and often has a "leathery" type of skin. Since the functional position of the sulcus should be recorded, a closed mouth impression technique is advocated, the patient carrying out muscular movements while the impression paste is setting. This is more accurate than the so-called "muscle trimming" methods where the operator manipulates the lips and cheeks of the patient. In the closed mouth method, the contraction is controlled in magnitude and location, and can be effected over all the concerned areas of reflection simultaneously. This latter point is important, since the necessary condition of the impression material, i.e., the consistency immediately before it hardens, exists only momentarily.

(iii) *The compressed position:* It is possible to record the sulcus reflection in a form when some tissue fluid lying below the mucosa has been expressed into adjoining tissue planes. This may be done locally or throughout the entire extent of the denture border. The tissues lying beneath the border are elastically compressed and tend to recoil and maintain close approximation with the border of the denture. The magnitude of increased extension between the resting and compressed positions is always very small.

(iv) *The distorted position:* It is never desirable to record a distorted or overextended sulcus form even in a first impression; it is unacceptable in a second impression. It must be realized that the facial muscles in their uncontracted or tonic state are readily displaced by small forces. Thus when a viscous impression material such as modeling composition is used, the force required to seat the impression deepens the sulcus considerably. This happens most markedly in the labial region where the displacement is not resisted because the lip margin is free. The result of this gross sulcus deformation is that muscles are displaced from their natural straight course, are stretched, and recoil both elastically and by contraction with sufficient force to displace immediately a denture made to such an impression (Fig. 10).

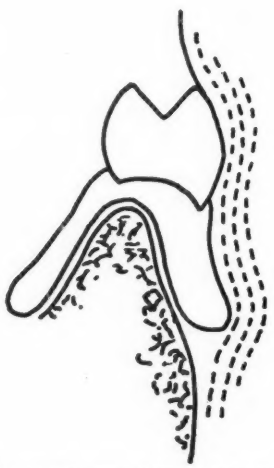


Fig. 10.—A denture displacing a muscle.

This is one of the faults most commonly seen in unsuccessful complete lower dentures. It arises through acceptance of an overextended first impression in modeling composition and failure to reduce the resultant special tray adequately before making the second impression. The fault may be avoided by cutting away the overextended modeling composition flange in the first impression, flaming locally, and reinserting; this process is repeated until the height of the composition flange, examined extraorally, is the same as the depth of the resting sulcus. Certainly indulgence in movements of the lip and cheek, wrongly designated as "muscle trimming," cannot hope to reduce the grossly overextended modeling composition impression. The alternative approach, and the one favored by the writer, is to make the first impression in a soft alginate impression material.

An understanding of the resting, functional, compressed, and distorted positions of the mucosal reflection is necessary for developing the best retention in the complete lower denture.

The best retention in any denture can be developed only as a result of seal. This is generally simply obtainable in the complete upper denture, but in the lower, it is not always possible to obtain a positive retention through the action of seal.

The first condition which may militate against positive retention of this nature is the accumulation of an excessive quantity of saliva in the floor of the mouth. This condition is permanent only rarely, but may be temporarily present immediately after the denture has been inserted when there is a copious reflex flow of saliva.

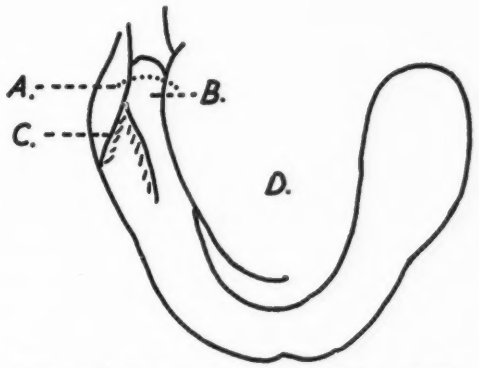


Fig. 11.—The position of the post dam on a lower denture. *A*, Post-dam position; *B*, retromolar pad; *C*, posterior buccal fold; *D*, tongue.

Second, the condition of the oral tissues may exclude the possibility of developing a seal. Seal may be developed either against the border of the denture, or against one or another of its polished surfaces; in the former instance it is known as border seal and in the latter as facial seal. The development of a facial seal is the better approach. In the complete lower denture, a facial seal is obtainable on the labial and buccal surfaces of the denture, and also through the action of the tongue against its posterior lingual surface. But, since the seal must completely encircle the fitting surface of the denture to be an effective aid in retention, border rather than facial seal must be developed in the retromolar and anterior lingual regions. This is easily done if, in these locations, there is a significant depth of resilient submucosa; if such a tissue is not present, then it is impossible to develop a positive retention through a sealing action.

Therefore, it is necessary to examine the retromolar and anterior lingual regions to arrive at a prognosis in respect to retention. Examination of the retromolar area constantly reveals the presence of a posterior buccal fold, which is a roll of tissue overlying the residual ridge and running up to the retromolar pad. The denture border should be sealed by this tissue, and should be shaped to a sharper edge to underlie this fold. On the lingual side, the tongue overlies the alveolar ridge to a greater or less extent and effects a facial seal. Only between these two areas is a border seal required. This is done by compressing the tissue of the retromolar pad, provided sufficient depth of soft tissue is present. This compression is usually effected by cutting a post dam on the working cast after a careful examination of the mouth (Fig. 11).

In the anterior lingual area, a significant amount of submucosa must be present below an elastic mucosa. This is often not found in the older atrophied mouth, and the midline area is generally the section which presents the greatest difficulty. With marked resorption, the superior genial tubercles are higher than the alveolar ridge, the two being connected by a ridge of bone. This is overlaid by a thin mucosa and submucosa which could not be compressed without pain or ulceration. Further, it is impossible to obtain a seal posterior to the tubercles as the superficial genioglossus muscle is again overlaid by thin atrophic tissue. Where compression is possible, it can be best obtained by using a viscous alginate impression material, or preferably by making a carding wax addition to the lingual border of a closely adapted tray made of acrylic resin.

Although it is not proposed to deal with details of the various impression techniques advocated, it is considered useful to make comment on the carding wax technique used to obtain lingual compression with the closely adapted special tray. This material is preferred to the so-called low fusing modeling composition tracing sticks. The latter do not maintain a desirable viscosity for a sufficient length of time, have too critical a softening temperature, which is often too high, and burn very readily. Moreover, too many variables are involved in assuring that the softened modeling composition addition is at the correct temperature when placed in situ. With the carding wax addition, a strip of wax of calculated dimension is fused to the border of the tray with a point flame. The purposes of this are to secure a union between the wax and the tray, and to produce a smooth surface rather than to soften the wax. The modified tray is placed in the mouth and the desired viscosity of the wax is assured by the mouth temperature. The tray is held in the mouth for one minute to allow the wax to be shaped by the tissues of the floor of the mouth. It must be remembered when withdrawing the tray from the mouth, when loading it with the impression paste, and when casting, that the wax is not rigid and care must be taken to avoid distortion.

TABLE I. THE CHOICE OF THE IMPRESSION METHOD

TYPE OF CASE	FINAL IMPRESSION TECHNIQUE
The uncomplicated case in which it is possible to develop a seal. This is a large group	1. Viscous alginate in a spaced special tray 2. Zinc oxide eugenol paste impression in a closely adapted, acrylic resin special tray, to which has been added an addition of carding wax to the lingual border
The atrophic case where seal is possible. Few cases are encountered in this class	Zinc oxide eugenol paste impression in a closely adapted tray modified lingually as above but with the mouth opened to a functional extent
The case where seal can be developed but where there is a large range of functional movement of the facial muscles. Few cases are encountered in this class	A closed mouth impression technique is required, the closely adapted acrylic resin impression tray being the base of the lower occlusion rim. After the centric relation record is made, a lingual border addition is made in carding wax, and the impression is made with the facial musculature functionally contracted
The case where it is impossible to obtain a border seal. This is a large group	Plaster of Paris, alginate, zinc oxide eugenol

The importance of the border of the impression has been stressed. Having taken care to secure this with accuracy, it is equally important that the finished denture should have an exactly equivalent border. Therefore, it is important that the stone cast from the impression should include the mucosal reflection and not be trimmed short. It must also be stressed that the border of the finished denture should be neither filed nor heavily polished. Removal of surface roughnesses by a very light stoning and buffing is the only permissible laboratory treatment of the denture border. Certainly, the habit of filing and polishing the denture border to some symmetrical and pleasing shape will ruin the retention of the denture.

3. *The Polished Surface.*—When considering the polished surface of the denture, it is helpful to include the buccal, labial, and lingual surfaces of the teeth. The position of the polished surface of the denture is determined largely by the position of the border, and by the position and width of the artificial teeth. The form of the base material between these two extreme positions may be modified by suitable carving.

I always use narrow posterior tooth forms to compensate for a reduction in the lateral width of the neutral zone. There is no evidence that even radical reduction in the width of the posterior teeth decreases the masticatory efficiency significantly.

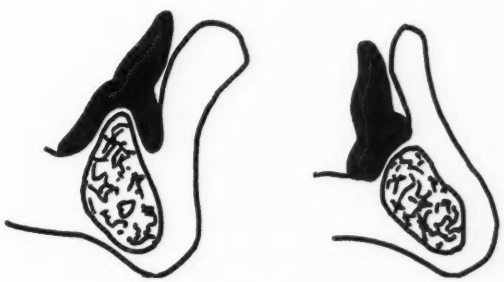


Fig. 12.—The change in inclination of the lower anterior teeth to accommodate to the changing lower lip.

The teeth, in the molar region, should be placed well over the buccal plate. This not only creates more tongue space where it is important to secure it, but also allows the development of a slightly more vertical polished surface against which a facial seal can be readily maintained. In the molar area, the development of a buccal flange is commended.[17] Lying under the middle group of fibers of the buccinator muscle, this is a retentive aid. Its use, however, is confined to those persons who display a good elastic quality in the mucosa. With atrophy, the extent of the flange must be reduced, and in most old people it is not possible to develop a useful buccal flange. When one is used initially, pain makes its early removal necessary.

In the anterior region, the teeth should be placed with their cervical ends over the ridge. In the young person, when the lip is everted, the anterior teeth may be given a forward inclination, but with atrophy the anterior teeth should be sloped progressively back, to accommodate to the changing lip position at rest and when the mouth is opened (Fig. 12).

4. *The Occlusal Surface.*—Too many complete lower dentures are ruined by setting the teeth up to some preformed idealistic concept of what constitutes the ideal occlusion. To accomplish this, lower premolar and anterior teeth are set outside the ridge, and well into the zone of action of the facial muscles. Again, lower molar teeth are set inside the ridge and do not allow sufficient tongue space. The teeth should be placed where the muscles and mucosa will allow, and not in a position to develop any idealistic concept of occlusion. The magnitude of the horizontal overlap which results or the degree of cross-bite obtained does not matter in the least.

When this principle is followed, it is found that the area of the occlusal surfaces of the lower teeth occluding with upper antagonists may be small indeed. However, this does not greatly reduce masticatory efficiency as assessed by the patient. In many cases, occlusion of the second premolar and first molars is all that is obtained, and yet a satisfactory function results. In fact, it is often wise to omit the second molar from the denture if it makes only a very small occlusal contact or lies over an inclined portion of the alveolar ridge which is sloping up to the mandibular ramus.

CONCLUSION

Put the teeth and denture base where the muscles and mucosa will allow, and develop the best possible retention and occlusion.

REFERENCES

1. Robinson, H. B. G., and Boling, L. R.: Ch. 19 in Cowdry, E. V.: Problems of Aging, ed. 3, Baltimore, 1952, The Williams & Wilkins Company, pp. 447, 467.
2. Massler, M.: Geriatrics and Geriodontics, New York J. Den. **26**:54-63, 1956.
3. Pedreira, R. A.: A Study of the Keratinization of the Oral Mucosa of Aged Males, J. D. Med. **6**:88-91, 1951.
4. Thompson, J. R.: The Rest Position of the Mandible and Its Significance to Dental Science, J.A.D.A. **33**:151-180, 1946.
5. Campbell, J.: Mandibular Displacement, D. Practitioner **5**:175-190, 1955.
6. Mershon, J. V.: Bite Opening Dangers, J.A.D.A. **26**:1972-1979, 1939.
7. Dick, J. C.: Observations on the Elastic Tissue of the Skin With a Note on the Reticular Layer at the Junction of the Dermis and Epidermis, J. Anat. **81**:201-211, 1947.
8. Lansing, A. I.: Aging of Elastic Tissue, Ciba Foundation Colloquia on Aging, ed. 1, London, 1955, pp. 88-108.
9. Burket, L. W.: Oral Medicine, ed. 2, Philadelphia, 1952, J. B. Lippincott Company, pp. 441-442.
10. Goldman, H. M.: Geriatric Changes in the Oral Mucosa, J. D. Med. **9**:86, 1954.
11. Gabel, D. P.: Unstable Lower Dentures, Brit. D. J. **45**:1-13, 1924.
12. Sicher, H.: Oral Anatomy, ed. 1, St. Louis, 1952, The C. V. Mosby Company, pp. 150-151.
13. Weinmann, J. P., and Sicher, H.: Bone and Bones, ed. 2, St. Louis, 1955, The C. V. Mosby Company, pp. 134-136.
14. Stones, H. H.: Oral and Dental Diseases, ed. 3, Edinburgh, 1954, E. & S. Livingstone, Ltd., pp. 531-533.
15. Massler, M.: Oral Manifestations During the Female Climacteric (the Postmenopausal Syndrome), Oral. Surg., Oral Med. & Oral Path. **4**:1234-1243, 1951.
16. Albright, F., Smith, P. H., and Richardson, A. M.: Postmenopausal Osteoporosis, J.A.M.A. **116**:2465-2474, 1941.
17. Fish, E. W.: Principles of Full Denture Prosthesis, ed. 5, London, 1952, Staples Press, p. 45.

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DETERMINATION OF VERTICAL DIMENSION BY PHONETICS

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THE DETERMINATION OF THE patient's natural vertical dimension has been a matter of guesswork. The proper use of phonetics is a means of measurement of the vertical dimension which eliminates inaccuracy.

The phonetic method is the speaking method[1] used in conjunction with the tattoo dots on the mucous membrane of the alveolar ridges.[2] These procedures help to avoid the establishment of an inaccurate vertical dimension. They can be used with the usual complete denture technique.

THE SPEAKING METHOD

The speaking method is a procedure of dental physiology. It is a method of using a physiologic stimulation of muscle activity during the production of speech sounds to measure the vertical dimension *before* the remaining natural teeth are lost. This measurement must be reproduced with accuracy in complete dentures.

The approximately 44 phonetic sounds in the English language require various levels of jaw opening during speech. One or more of the six sibilants generally cause the mandible to be on the closest level to the maxillae during speech. It may be simpler to use only the sibilant *s* of ye*s* in the measurement of vertical dimension. This sound is the most frequently used of the sibilants in speaking and reading,[3] and it gives an accurate measurement for all patients.

The patient is directed to close the teeth into centric occlusion, and the centric occlusion line is drawn on a lower anterior tooth at the horizontal level of the incisal edge of an upper incisor (Fig. 1). This line serves as a reference line.

The closest speaking line (Fig. 2) is then drawn on the same lower anterior tooth while the patient pronounces the *s* of ye*s*. The patient is directed to speak or read *rapidly* from a magazine in order to check the accuracy of the location of the closest speaking line. In measuring with the individual word, the patient could control the level of the mandible voluntarily. It is impossible to control the mandible during rapid speech, as all voluntary muscular control over mandibular position is lost. While the patient speaks, I listen for the *s* sounds and, during the up and down movements of the mandible, I watch the closest speaking line coincide with the upper incisal edge. If the upper line is too high or too low, the deviation will be in a constant relation to the upper incisal edge. If necessary, the closest speaking line is redrawn with the *s* sound of the individual word, ye*s* as a guide, or it

Presented on the television program of The American Denture Society, Chicago, Ill., Feb. 4, 1955.

Received for publication Sept. 9, 1955.

is drawn free hand on the lower anterior tooth until this line coincides with the incisal edge of the upper tooth while the patient is pronouncing the *s* sounds.

The closest speaking space is the distance between the lower centric occlusion line and the upper closest speaking line. This space is the measurement for vertical dimension. This closest speaking space happens to be 4 mm. in the patient shown in Fig. 2. When these natural teeth are lost, the same 4 mm. closest speaking space must be present in the artificial dentures. If the closest speaking space is too small, the vertical dimension is increased beyond normal. If the space is too large, the vertical dimension of the complete dentures is decreased beyond normal.

Fig. 1.

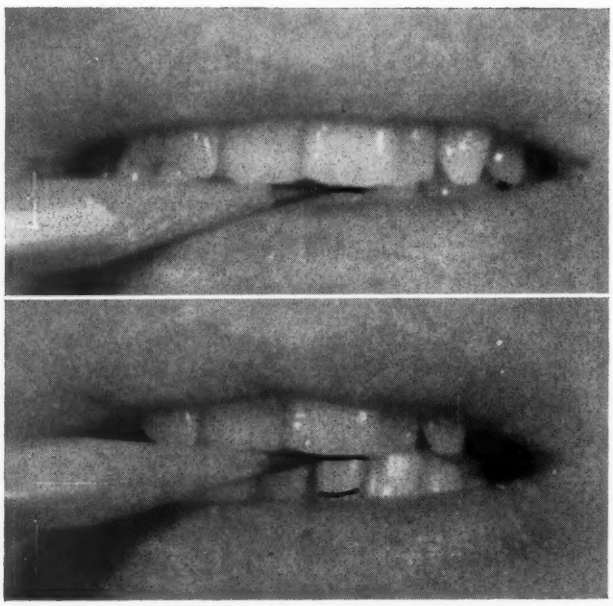

Fig. 2.

Fig. 1.—The centric occlusion line is drawn on the lower anterior tooth at the horizontal level of the upper incisal edge, while teeth are closed in centric occlusion.

Fig. 2.—The closest speaking line is drawn on the lower anterior tooth at the horizontal level of the upper incisal edge while the patient sounds the *s* of yes. The distance from the centric occlusion line (lower) to the closest speaking line (upper) is the closest speaking space. This space is the measurement for vertical dimension and is accurately registered in the natural dentition, trial dentures, and completed dentures.

THE CLOSEST SPEAKING SPACE AND THE FREE-WAY SPACE

The closest speaking space is *not* the free-way space. The measurement of vertical dimension by means of the closest speaking space of the speaking method should not be confused with the free-way space of the rest position method. Usually these two spaces are different in the same individual, although they can be the same coincidentally.

The free-way space is determined when the mandible and the muscles involved are at complete *rest*. The closest speaking space is determined when the mandible and the muscles involved are in phonetic *action*.

The average free-way space measures 3 mm. The closest speaking space measures from 0 to 10 mm. and must be exact for each patient. An average is insufficiently accurate.

The measurement of the free-way space can be quite inaccurate. If a group of dentists would measure the closest speaking space on a single patient, the measurements would be the same within 1 mm.

The free-way space determination may require many minutes or hours to measure and recheck. The closest speaking space can be determined in seconds.

The measurement of the free-way space depends on the patient's ability to relax, and sedation may be necessary in order to obtain the necessary relaxation. The measurement of the closest speaking space does not require such relaxation because it requires activity of the muscles.

The measurement of the free-way space requires the patient's cooperation, but the measurement of the closest speaking space is not dependent upon patient cooperation because he loses voluntary muscle control over the mandible and indicates the correct vertical dimension involuntarily while reading or speaking rapidly.

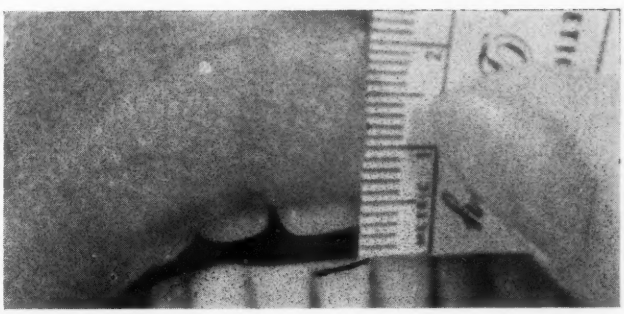

Fig. 3.—These dentures have an interincisal space when the closest speaking space is measured as shown. Note the centric occlusion line on the lower tooth. The closest speaking line, denoting the closest level of the mandible to the maxillae, is at the upper incisal edge, while sounding the *s* of *yes*.

TECHNIQUE WITH EXISTING DENTURES

When pre-extraction records are not available for a patient who is wearing dentures, the problem of determining the vertical dimension is generally a matter of guesswork. The speaking method[1] and the tattoo dot method[2] make it possible to guess the vertical dimension with greater accuracy when existing dentures are to be replaced. The technique of measurement is the same as with natural dentitions (Figs. 1, 2, and 3). The diagnosis must determine whether the vertical dimension is to be reproduced or increased or decreased in the new dentures. This requires judgment, and the history of the case should be analyzed for helpful information. If the old dentures have been used comfortably for many years, it might be assumed that the ridges and the dentures have adjusted to a normal vertical dimension. If the teeth click or if the closest speaking space is obliterated during speech, the vertical dimension should be reduced, and the amount of reduction is determined arbitrarily.

Fig. 4.

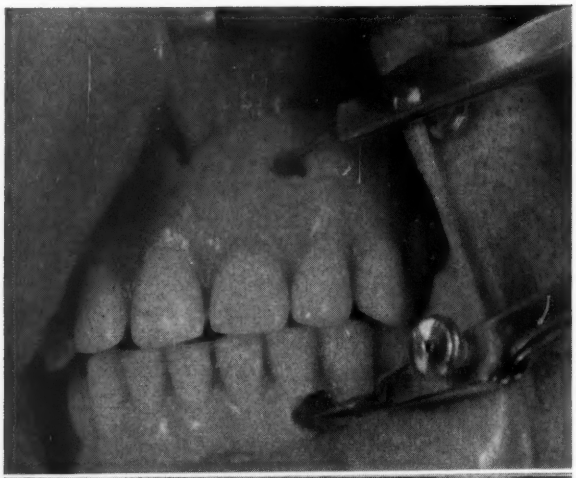

Fig. 5.

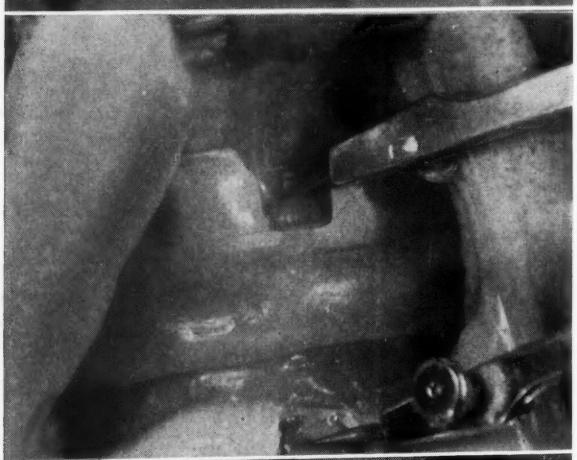

Fig. 6.

Fig. 4.—The distance between the dots is measured while the teeth of the existing dentures are closed in centric occlusion. Tattoo dots were placed into mucous membrane through the holes in the dentures.

Fig. 5.—The distance between the tattoo dots is measured through U-shaped openings in the occlusion rims. The distance between the dots can be the same in the new dentures as in the old dentures, or it can be increased or decreased with accuracy.

Fig. 6.—The distance between the tattoo dots is measured through V-shaped openings in the trial dentures while the teeth are in centric occlusion.

Measurements between tattoo dots on the mucous membrane of the residual ridges are used to transfer the vertical dimension of the old dentures to the new ones. Holes are cut into the labial flanges of the dentures. Tattoo dots of India ink are placed with a Luer Lok syringe through these holes into the mucosa. The distance between these dots is measured while the patient is closed into centric occlusion (Fig. 4), and can be reproduced in the new dentures, or increased or decreased with accuracy according to the diagnosis. V-shaped openings are cut into the labial flanges of the occlusion rims and the new trial dentures to measure the distance between the tattoo dots during the construction of the new dentures (Figs. 5 and 6).

TECHNIQUE WITHOUT RECORDS OR DENTURES

When there are no pre-extraction records, and the patient has not worn dentures which would aid in the construction of new dentures, the determination of vertical dimension is a matter of guesswork. Nevertheless, phonetic principles can be used as a guide. The dentures are constructed by the usual technique, except that the closest speaking space is determined to aid in guessing at the patient's natural vertical dimension.

Fig. 7.—The vertical dimension of the occlusion rims of a patient without pre-extraction records or previous dentures is being measured. The patient sounds the *s* of *yes* while the closest speaking space is measured. The incisal edge level of the lower occlusion rim is the centric occlusion line, and the incisal edge level of the upper occlusion rim is the closest speaking line.

The construction of the complete dentures is carried out in the usual method until the maxillomandibular relationship of the occlusion rims is determined. The width of the occlusion rims is trimmed to allow for the normal space for the tongue, and the lingual surfaces of the upper and lower anterior portions are cut out to simulate the approximate width and shape of the teeth. Adhesive powder is sprinkled into the occlusion rims to make certain the patient can speak freely.

The patient is instructed to pronounce the sound *s* of ye*s* in order to determine the approximate closest speaking space (Fig. 7). Then the patient is instructed to speak or read rapidly aloud from a magazine so that his voluntary muscular control is lost. By sight, or by measuring, the approximate closest speaking space is noted. The occlusion rims must not touch together during speech as this would indicate that the vertical dimension was too great. A closest speaking space of perhaps 2 or more millimeters is decided upon arbitrarily, depending upon the facial appearance and comfort of the patient.

The closest speaking space can be determined more accurately with the artificial teeth set up in wax, and it is rechecked at that time.

The closest speaking space can range from 0 to 10 mm., in different patients, and this indicates that there is no average closest speaking space. The vertical dimension must not be increased beyond the normal for each patient.[4] It is better to use a vertical dimension that is too small than to use one that is too great. The principles of sound formation[2] must be understood in order to achieve the attainable accuracy in guessing at the natural vertical dimension. The judgment and experience of the dentist must be relied upon in guessing the patient's natural vertical dimension.

At times it is necessary to be a good detective and ask the patient questions, or let him tell you all he can about the positions of his natural teeth before they were removed. Often the patient can understand and remember whether the front teeth were overlapped in a vertical direction and how much, or whether they were in an edge-to-edge relation. The hands may be used to indicate these relative positions in order to assist the patient to express himself. If the natural teeth were in an edge-to-edge relationship, the closest speaking space might have been zero. There should be no interincisal space[2] visible at the anterior teeth at the closest level of the mandible in relation to the maxillae while the patient speaks rapidly. Therefore, the vertical overlap must equal, and at times be greater than the closest speaking space.

Sufficient adhesive powder is sprinkled into the trial dentures to make certain the patient can speak freely without the inhibiting effect of loose or slipping dentures. The closest speaking space is measured in the same manner as in a natural dentition and recorded. The dentures are finished and processed in the usual manner. If the complete denture procedure is carefully followed at the chair and in the laboratory, the closest speaking space as determined in the trial dentures should be the same when the completed dentures are delivered to the patient.

PATIENT EDUCATION

When there are no pre-extraction records it is advisable to explain the problem to the patient and inform him that we are guessing at the distance between the upper and lower jaws. It is *his* problem and responsibility.

If patients present themselves *before* the loss of their remaining natural teeth, we should measure the closest speaking space and record it, because it is now *our* responsibility for the reproduction of the natural vertical dimension in the complete dentures.

When patients present themselves after the loss of their remaining natural teeth and there are no pre-extraction records, it is advisable to speak frankly. To avoid misunderstanding, they must be told that if gums shrink, or if teeth wear, it might be necessary to make a second set of dentures at the resulting vertical dimension. Therefore, after building your first dentures for these patients, the closest speaking space should be measured periodically. Measurements should be made at or a few days after insertion, and about every six months thereafter. As soon as the patient is reasonably comfortable with a normal color and texture

of the mucous membrane, and when the closest speaking space remains constant, without further changes in the maxillomandibular relationship, it is then *assumed* that the vertical dimension is normal. Many of these patients without pre-extraction records develop such extreme maxillomandibular relationship changes that the teeth on the dentures appear as in a Class III malocclusion. The resultant closest speaking space is generally within normal when it is checked. This indicates that the vertical dimension existing at that time should be duplicated in the new dentures and the anterior teeth rearranged to appear normal and cause normal sounds.

REFERENCES

1. Silverman, Meyer M.: The Speaking Method in Measuring Vertical Dimension, J. Pros. Den. **3**:193-199, 1953.
2. Silverman, Meyer M.: Pre-extraction Records to Avoid Premature Aging of the Denture Patient, J. Pros. Den. **5**:465-476, 1955.
3. Dewey, Godfrey: Relative Frequency of English Speech Sounds, Cambridge, Mass., 1923, Harvard University Press.
4. Silverman, Meyer M.: Vertical Dimension Must Not Be Increased, J. Pros. Den. **2**:188-197, 1952.

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A BIO-MECHANICAL APPROACH TO THE PROBLEM OF PROSTHETIC OCCLUSION

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ONE OF THE PROBLEMS confronting the dental profession centers around the type of artificial posterior teeth best suited for dentures. In other words, the problem is which occlusal form lends itself most favorably to prosthetic occlusion?

TYPES OF ARTIFICIAL TEETH

In a broad analysis, there are two types of artificial posterior teeth available. They are the anatomic or cusp teeth and nonanatomic or cuspless teeth. To refer to nonanatomic teeth as mechanical teeth is a misnomer since all artificial teeth are mechanical teeth. Swenson[1] states, "Strictly speaking, all artificial teeth are geometrically designed, but the term anatomic is used for those teeth which more nearly resemble the natural dentition."

The cusp type of artificial tooth is characterized by its cusps and cusp inclines, in imitation of those found in natural teeth. The artificial cusp tooth may have many variations or modifications which manifest themselves in varying degrees of cuspal height ranging from 5 to 45 degrees. Regardless of the amount of cuspal height or reduction, the basic design and principle of all cusp teeth is similar in that some degree of cuspal inclination is maintained.

The cuspless type of artificial posterior tooth does not imitate the natural tooth and is characterized by its flatness and absence of cuspal inclines. The difference between the various types of cuspless teeth is in their occlusal form or design. However, they are all similar in that they are all cuspless, flat, and have a two-dimensional occluding surface (Fig. 1).

FUNCTION AND FORM OF NATURAL TEETH

In the natural dentition, the teeth function in accordance with the curved movements of the mandible. Natural teeth, as part of the masticatory apparatus, function in harmony with the masticatory muscles and mandibular movements.

The masticatory movements are three dimensional. They are a fusion of three basic movements: vertical, lateral, and anteroposterior or protrusive. The occlusal surfaces of the natural teeth are also three-dimensional. The cusps have

Received for publication June 20, 1955; revised by the authors Jan. 5, 1956.

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length and width, which allow for the lateral and protrusive movements, and height, which provides for the vertical movements.

In conformity with the pattern of occlusion and mastication found in nature, the teeth are arranged in two arches, each arch following a specific curvature. The dental arch conforms to a parabolic curve and the occlusal arch conforms to an anteroposterior compensating curve and a lateral or transverse curve. Both curves are necessary in order to obtain occlusal balance and proper distribution of the forces of mastication. The curvatures of the occlusal surfaces of the dental arches differ in that the upper curvature is convex and the lower curvature is concave.

Although the ideal occlusion is rarely seen clinically in the natural dentition, the cuspal inclines provide for balanced occlusion.[2]

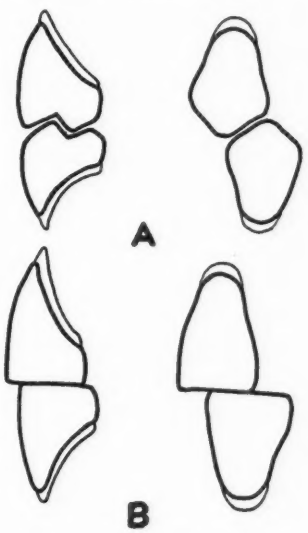

Fig. 1.—*A*, The anatomic or cusp tooth. *B*, The nonanatomic or cuspless tooth.

FUNCTION OF THE DENTITION AND OF DENTURES UNDER DIFFERENT CONDITIONS

In the dentition, the teeth are attached to the alveolar process. The shock of the forces of functional and nonfunctional movements of the mandible are absorbed by each tooth individually, and by the teeth collectively through their attachment apparatus.

In the edentulous mouth, there exists an entirely different situation, creating a problem in prosthetic occlusion.

In an artificial denture, each tooth is attached to a single denture base which rests on soft, movable, and irritable tissue. Thus, forces are not absorbed by individual teeth but are first reflected throughout the entire denture base, and then absorbed by the supporting structure.[3] Craddock[4] states, "It is clear, however, that natural dentitions and artificial ones function under different conditions of retention and support, and it is therefore conceivable that the most efficient substitute might differ considerably from the natural organ which it replaces."

DISADVANTAGES OF ARTIFICIAL CUSP TEETH

In recent years there has been a growing awareness that artificial cusp teeth, when used for complete dentures, may be both harmful and detrimental to the supporting tissues. Cusps and cusp inclines, which result in comfortable and efficient mastication in the natural dentition, may cause discomfort and inefficient mastication in the artificial dentition. This is due mainly to the problems associated with achieving proper occlusion; that is, in coordinating the functional cuspal inclines. The complexity of the problem stems from the great number of functional inclined planes which must be correlated and which must harmonize with mandibular movements in four directions; right lateral, left lateral, protrusive, and vertical, depending upon the height of the cuspal inclines.

Assuming that one has been successful in coordinating all of these inclined planes, and in creating cuspal harmony in all mandibular excursions, how long can this harmony be maintained after the dentures have been inserted in the mouth? This is governed by two factors which usually result in a change in cuspal relationship. Shortly after new dentures are inserted in the mouth, a certain amount of settling inevitably occurs. As times goes by, a second factor influences cuspal harmony; namely, residual ridge resorption. Both of these processes will result in a loss of cuspal harmony and lead to cuspal interference which may not have been present originally. Little[5] states, "Another contributing factor in the loss of correct tooth interdigitation is the fact that the ridge resorption of the maxilla is not only on the crest of the ridge, but also on the labial and buccal surfaces. This allows the upper base to travel upward and backward. After the dentures are inserted, any ridge change permits the two dentures to drift in opposite directions, which of course, will disturb the cusp interdigitation originally established." One is forced to conclude that the cusps of natural teeth, when reproduced in artificial teeth, may be both undesirable and harmful. Others have arrived at the same conclusion.[3, 6]

As a result of the problems associated with cusp teeth, many cuspless tooth forms have been developed. Sears[7] lists 41 different designs which, he states, represent the most significant ones.

DISADVANTAGES OF FLAT CUSPLESS TEETH

The use of cuspless teeth has resulted in the elimination of cuspal interference, decrease of lateral stress, and simplification of tooth articulation. However, with all their advantages, flat cuspless tooth forms still present certain problems. All cuspless tooth forms have flat, two-dimensional occluding surfaces and therefore cannot conform to the three-dimensional, arcuate movements of the mandible. They have width and length but, since they do not have height, they cannot provide for the important vertical component of mastication. This vertical component is an integral part of mastication, and its elimination results in decreased masticating efficiency.[8]

It has been noted that the natural teeth, their alignment in the arches, and the masticatory movements, are all characterized by curvature in form and function.[3] Flat cuspless teeth do not conform to this basic physiologic pattern of the oral cavity.

Another problem presented by two-dimensional cuspless occlusal forms is their falure to provide occlusal balance. Flat upper and lower occlusion rims which occlude in centric position do not have a balancing posterior contact in either lateral or protrusive positions (Fig. 2). To compensate for this situation, attempts are made to set flat cuspless occlusal forms to a compensating curve. In doing so, considerable grinding of the occlusal surfaces is necessary and, at best, the end result is never completely satisfactory[8] (Fig. 3).

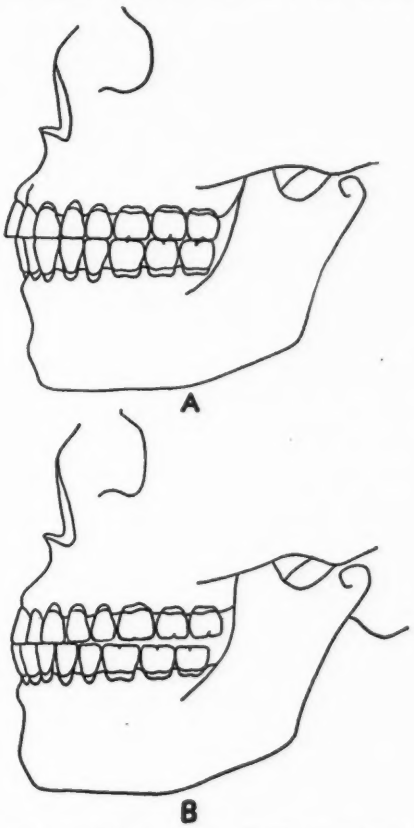

Fig. 2.—*A*, Flat cuspless teeth in centric position. *B*, Flat cuspless teeth in protrusive position. Note the lack of posterior contact.

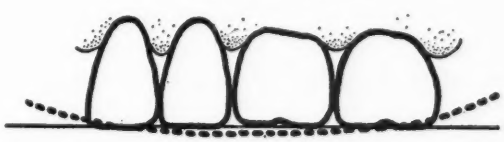

Fig. 3.—The illustration indicates the difficulty in adapting flat teeth to a perfect curvature.

CONCENTRIC CURVATURES OF THE SAME RADIUS APPLIED TO PROSTHETIC OCCLUSION

By prosthetic occlusion is meant an artificial substitute for physiologic occlusion. Artificial dentures are mechanical in structure but the mechanics of their construction must be such that they will operate in harmony with all the components

of the masticatory apparatus, thus restoring physiologic function. Obviously, neither cusp teeth nor flat cuspless teeth are ideally suited to meet the needs of prosthetic occlusion.

The occlusal surfaces of artificial teeth for prosthetic occlusion should be biomechanical: biologic in function and mechanical in form and structure.

In order to improve current designs of artificial teeth so that optimum occlusion is obtained, certain mechanical or physical principles should be incorporated in tooth design. The mechanical principle to be applied must be one which is compatible with the basic curvature of the human masticatory apparatus, as previously indicated. The occlusal pattern to be discussed is based upon the principle of concentric curvatures of the same radius.

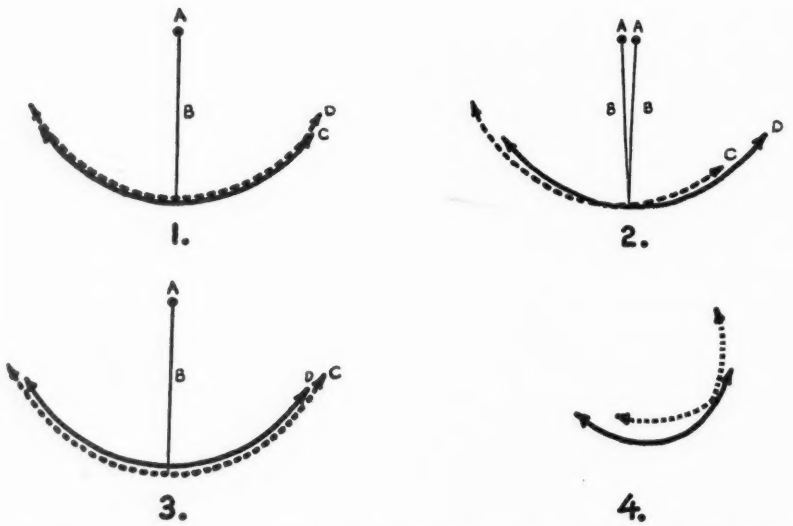

Fig. 4.—Schematic illustration of the principle of concentric curvatures of the same radius.

1. *C* and *D* represent two curvatures: Note the continuous contact. *A*, The common center; *B*, the same radius.

2. *C* and *D* represent two curvatures: Note the lack of contact. *A*, Different centers; *B*, the same radius.

3. *C* and *D* represent two curvatures: Note the lack of contact. *A*, A common center; *B*, a different radius.

4. Represents two imperfect curvatures: Note the lack of contact.

In suggesting the application of the principle of concentric curvatures of the same radius to prosthetic occlusion, we are not implying that the dentition functions according to the spherical concept as propounded by Monson. Our premise is that the principle of concentric curvatures of the same radius is compatible with the masticatory apparatus and is applicable only to prosthetic occlusion.

The principle may be defined as follows: concentric curvatures of the same radius are those curved surfaces which have the capability of moving one upon the other in all directions, producing three-dimensional movements, maintaining continuous contacts without becoming dislodged in any direction (Fig. 4).

APPLICATION TO AN ADJUSTABLE ARTICULATOR

The principle of concentric curvatures of the same radius can be employed with any adjustable articulator such as the Hanau Model "H" by attaching a convex occlusal arc to the upper member and a concave occlusal arc of the same radius to the lower member of the articulator. When the condylar inclination and the incisal inclination are coordinated with the occlusal arcs, they will move one upon the other, maintaining continuous contact in every direction (Figs. 5, 6).

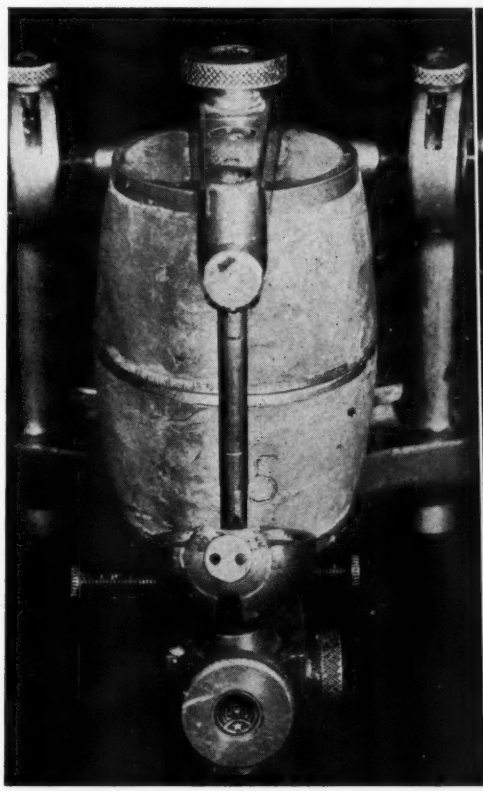

Fig. 5.

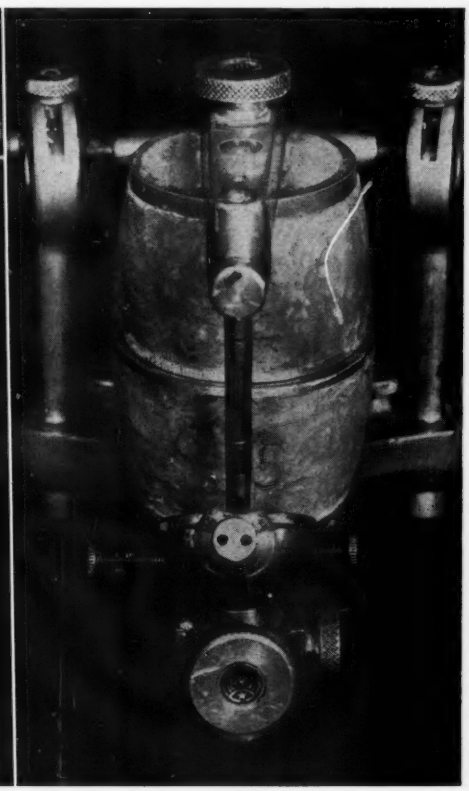

Fig. 6.

Fig. 5.—Convex and concave arcs of the same radius attached to a Hanau articulator in centric position.

Fig. 6.—The two arcs in a protrusive relation. Note the continuous contact.

This is possible because the articulator is moved on an arcuate plane about a stationary center, the upper member being supported at two points in the slots angularly adjusted to an arcuate plane concentric with the occlusal arcs.

A close approximation to a circle arc is achieved by tilting the bearing slots of the articulator so that the extreme bearing position lies on the arc of rotation (Fig. 7). There is sufficient clearance or play in the movable members to make this practical with a curvature of a 4 inch radius limited to a ½ inch of movement.

Referring to Fig. 7, *O* equals center of a 4 inch sphere.

M-M equals occlusal plane of 4 inch curvature.

P equals pivot of articulator in center position.

R-R equals arc through point *P* about center *O*.

(This is the path the pivot *P* must follow when the upper member of the articulator is retracted).

A equals point on upper occlusal surface.

B equals point on lower occlusal surface.

Q equals points on arc *R-R*.

X-X equals straight line running through points closely approximating points *P-Q*.

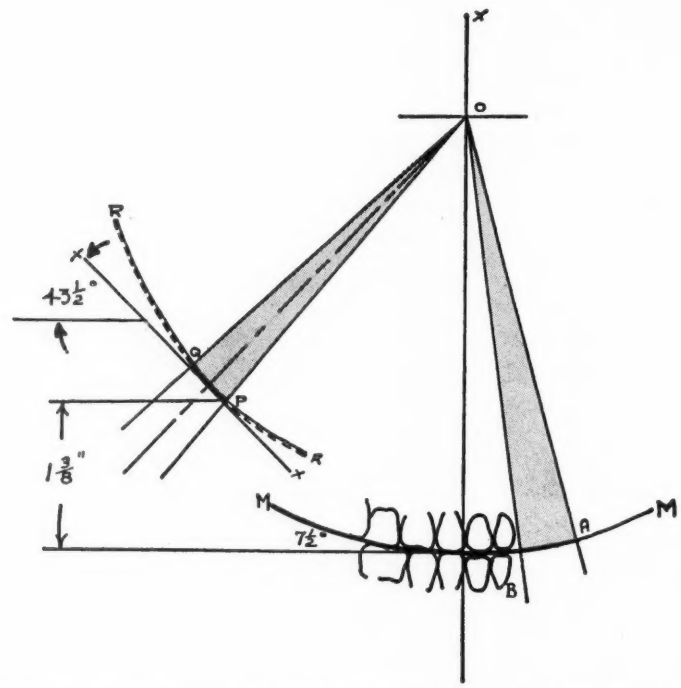

Fig. 7.—A schematic drawing which illustrates the application of the principle of concentric curvatures on the Hanau or similar articulator.

When point *A* on the upper surface is retracted to point *B* on the lower surface, the pivot point is moved to point *Q* on arc *R-R*. These corresponding motions are identical angular motions about the common center *O* indicated by shaded areas. It will be observed that arc *R-R* on the arcuate line *P-Q* is closely approximated by the straight line *P-Q* on line *X-X*. Line *X-X* forms an angle of 43½ degrees with respect to horizontal. This is the angular setting which makes the Hanau articulator work, but it is essential that the bottom of the occlusal arc *M-M* be 1⅜ inches below the pivot point *P* for this particular angle.

Swenson,[1] in discussing occlusion, stresses the importance of concentric curves (Fig. 8).

CONCENTRIC CURVATURES OF THE SAME RADIUS INCORPORATED IN THE OCCLUSAL DESIGN

The principle of concentric curvatures of the same radius has been incorporated in the design of cuspless occlusal forms which, unlike existing cuspless forms, are not flat (two-dimensional) but arcuate (three-dimensional). These cuspless, occlusal forms have been given the name "Bio-Mechanical Posteriors" because they are constructed in conformity with the above-mentioned mechanical principle, providing movements corresponding to the physiologic function of occlusion and mastication with a dentition. Their occlusal surfaces have height and depth, width and length. The height is formed by the convexity of the upper occlusal surface, the depth, by the concavity of the lower occlusal surface (Fig. 9).

Since the occlusal pattern of the Bio-Mechanical Posterior teeth is three-dimensional, it functions in harmony with the arcuate movements of the mandible. The anteroposterior curvature makes possible protrusive balance and bilateral balance results from the lateral or transverse curvature.

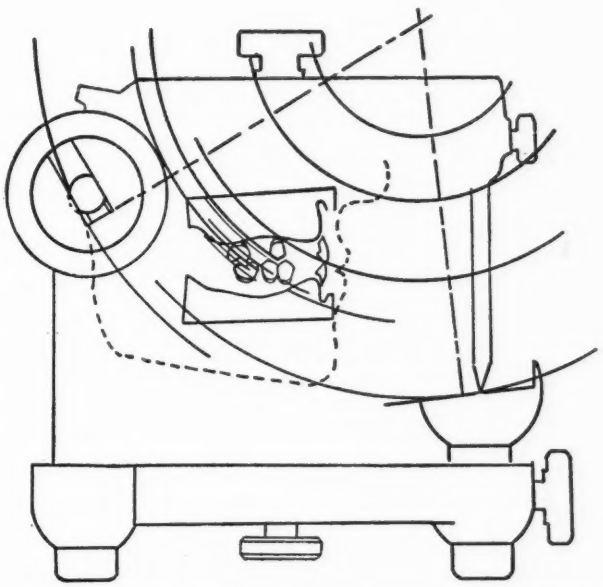

Fig. 8.—". . . teeth set to harmonize with concentric curves that are scribed from the rotational center. The rotational center is established by a line drawn at right angles to the controlling end factors, condylar and incisal guidance." (From Merrill G. Swenson, Complete Dentures, ed. 3, St. Louis, 1953, The C. V. Mosby Co., Fig. 317, p. 247.)

In complete denture construction, the form and function of the occlusal arches as units are of prime importance, since function is performed by the denture as a whole.[9] Individual artificial teeth, as part of the arch, should have similar forms. The compensating occlusal curvature of the dental arches can best be created when the teeth themselves are curved individually. The individual occlusal surfaces of the Bio-Mechanical Posteriors are preformed or precarved to a designated average curvature (Fig. 10). As a result, the upper and lower posterior

teeth form convex and concave occlusal surfaces which are identical and which create a curved relationship providing maximum continuous tooth contact in all mandibular movements, resulting in balanced occlusion.

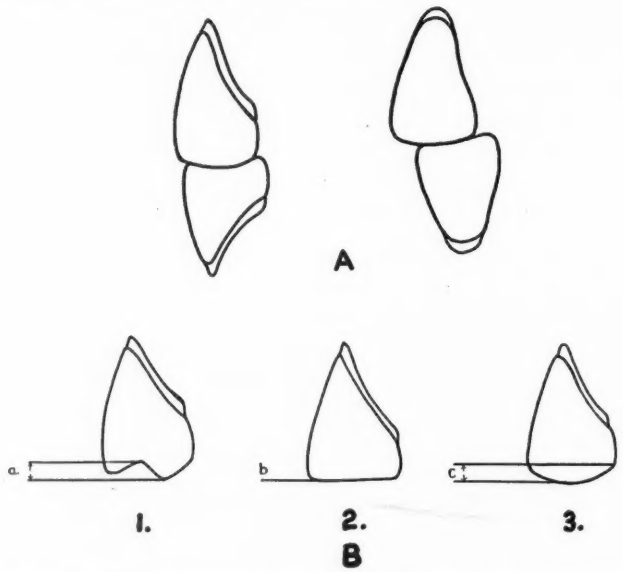

Fig. 9.—*A*, Bio-Mechanical Posterior teeth illustrating the anteroposterior and transverse curvature. The occlusal surface of each tooth is a segment of a designated curvature. *B*, Comparison of the occlusal surfaces of the three basic types of artificial teeth: cusp, flat, and the Bio-Mechanical cuspless tooth. *1*, Cusp tooth; *a* indicates the height of the cusp. *2*, Flat cuspless tooth; *b* indicates absence of height. The tooth has length and width only. *3*, Bio-Mechanical tooth; *c* indicates the height of the occlusal surface, although it is cuspless.

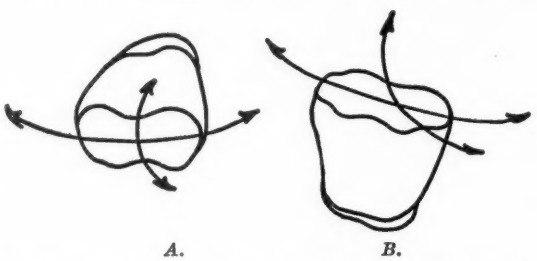

Fig. 10.—*A*, The convexity of the occlusal surface of each upper tooth in all directions. *B*, The concavity of the occlusal surface of each lower tooth in all directions.

Bio-Mechanical Posteriors offer no cuspal obstruction in any functional or nonfunctional movement, whether the movement is recorded or not. Opposing teeth function freely in eccentric ranges with a minimum of horizontal force. Occlusal surfaces of the Bio-Mechanical Posteriors present neither buccal nor lingual external cusps. Anatomic carvings are embedded within the curved occlusal surfaces (Fig. 11). The cusps, triangular ridges, marginal ridges, fossae, grooves, and supplemental grooves, instead of lying above the occlusal surfaces of the teeth, lie on the same surface.

It is generally known that the form of the natural tooth does not remain constant. Early in life the natural teeth usually show prominent cuspal forms. Later

on, changes occur so that often the cusps are completely obliterated. It can be said, therefore, that both cusp and cuspless teeth exist in nature. In this connection, the Bio-Mechanical Posterior tooth may also be described as a well-worn anatomic cusp tooth. During mastication, the concave occlusal cutting edges of the lower teeth move without interference across the convex occlusal cutting edges of the upper teeth. This results in efficient mastication. In addition, the carvings provide ample sluiceways for the escape of food. The occlusal surfaces too, are divided into multiple segments by the many spillways. As a result, only small tooth areas come into contact during functional movements, assuring efficient mastication.[2] These spillways also serve another purpose in preventing the packing of food into the occlusal surfaces of the teeth. The spillways are of the same depth as the cone-shaped fossae, tending to make the occlusal surfaces self cleansing.

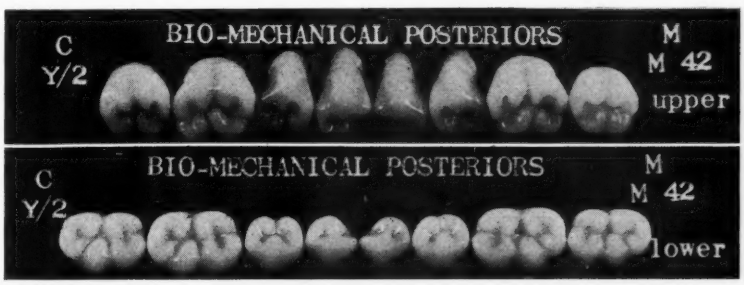

Fig. 11.—Bio-Mechanical Posteriors. Note the resemblance to natural teeth.

PROCEDURE FOR SET-UP AND ARRANGEMENT OF THE TEETH

Bio-Mechanical Posteriors, like any other artificial teeth, can be set up in the usual manner; however, the mechanical principle of concentric curvatures of the same radius lends itself to the development of a new and somewhat different procedure for setup and arrangement of the teeth.

The usual method for setting up teeth consists of positioning them first in centric occlusion, and then adjusting them by manipulation and grinding to obtain protrusive and lateral balance. When the Bio-Mechanical Posteriors are used, exactly the reverse is done. At the very start, the teeth are set to proper working, balancing, and protrusive occlusions, thereby establishing unilateral, bilateral, and protrusive balance. Once balance is established, the teeth automatically fall into correct centric occlusion. In the procedure to be outlined, the teeth are set to proper occlusal balance in all functional ranges at the very outset.

Any adjustable articulator such as the Hanau Model "H" may be used for the set-up and arrangement of Bio-Mechanical Posteriors. The casts are oriented on the articulator by means of a face-bow, or mounting-jig. The condylar inclinations are set at 30 degrees, or if intraoral registrations are used, they may be set accordingly. The incisal guide is set temporarily at 0 degrees.

With the articulator in centric position, the six upper anterior teeth are set according to measurements obtained in the mouth. The two lower central incisors are set so that there is no vertical overlap of the upper anterior teeth in centric position. The position of the lower anterior teeth will determine the amount of horizontal overlap of the upper anterior teeth, and the amount of functional range

necessary to bring the upper and lower anterior teeth into an incisive position. Before proceeding further with the set-up, the limit of functional range which will be permitted must be established, and the incisal guide must be reset to its correct position in harmony with the condylar inclination.

The lock nut for the incisal guide adjustment is loosened so that the incisal guide is no longer in contact with the incisal guide pin. The articulator is moved into protrusive position so the upper and lower central incisors are edge-to-edge (Fig. 12). The center locks are set so that the instrument cannot move beyond this protrusive position. With the instrument still in protrusive position, the incisal guide is moved until it comes into contact with the incisal guide pin and is locked in this position. This establishes the correct incisal guidance.

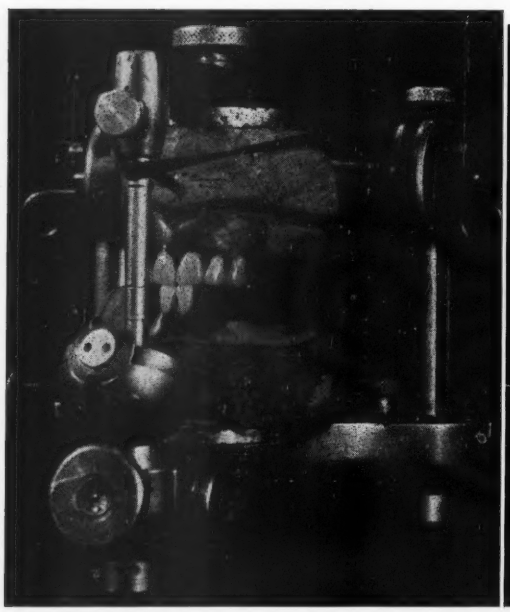

Fig. 12.

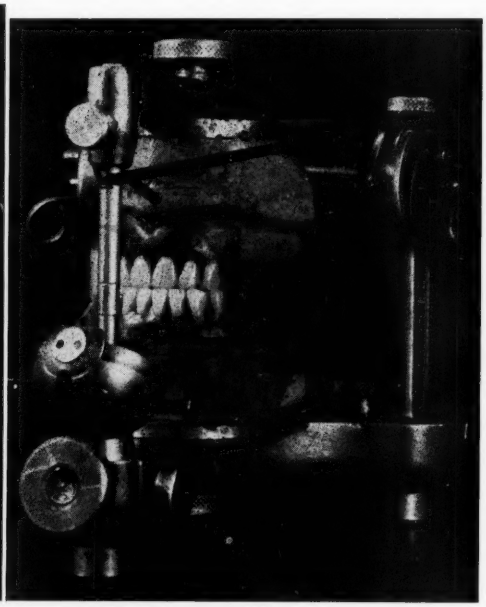

Fig. 13.

Fig. 12.—Lower central incisors in an edge-to-edge relationship. The articulator is locked in a fixed protrusive position.

Fig. 13.—The anterior teeth are in an edge-to-edge relationship. The lower first bicuspids are in place. The articulator is locked in a fixed protrusive position.

The remaining lower anterior teeth are set with the instrument in a protrusive position. The articulator can be locked in a protrusive position in one of two ways. An insert may be placed into the horizontal condylar guides so that they prevent the terminals of the condylar shaft from returning to centric position, thus maintaining the articulator in a fixed protrusive position. Or rubber bands are placed around the lock nuts for the horizontal condylar guide adjustments and the lock screw for the incisal pin. With the articulator fixed in a protrusive position, the remaining lower anterior teeth are set in their proper position in relation to the ridge, and in an edge-to-edge relationship with the upper anterior teeth. The two lower first bicuspids are placed so that their occlusal surfaces are at the same height as the tips of the lower cuspids (Fig. 13). They should be so posi-

tioned that the central fossa of each is in line with the crest of the posterior ridge, and the tooth is in proper alignment with the lower anterior teeth. Usually, the upper cuspids must be ground to occlude properly with the lower bicuspids. Before proceeding further, the instrument is moved to right and left lateral positions to correct for interferences between the anterior teeth in those positions.

THE COMPENSATING CURVE

The compensating curve runs from the distal side of the first bicuspids, through the occlusal surfaces of the lower molars, to the center of the retromolar pads. Since the position of the first bicuspids has been established, only the positions of the second molars remain to be determined. Two pieces of wax are placed on the crest of the ridge just anterior to the retromolar pad. An occlusal arc

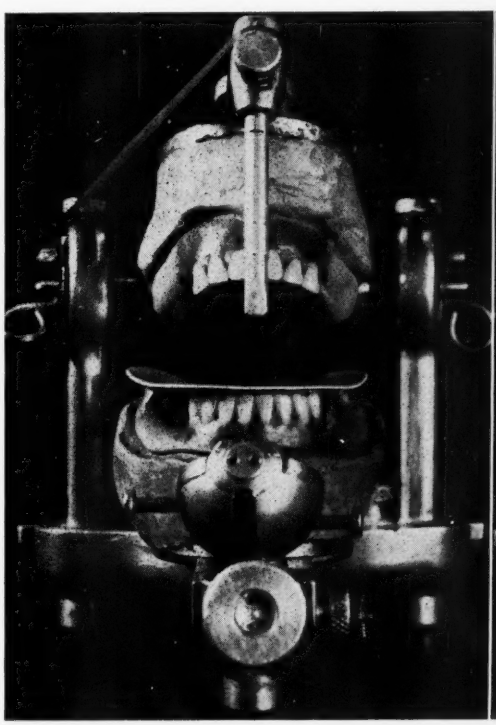

Fig. 14.

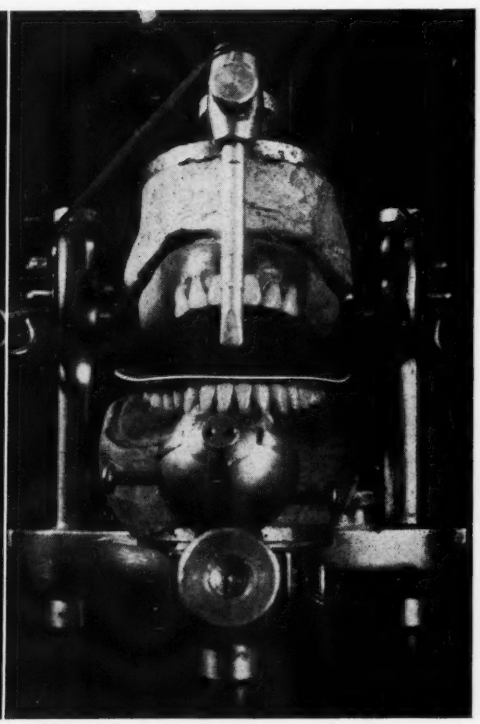

Fig. 15.

Fig. 14.—The occlusal curvature of the posterior teeth is established and located.
Fig. 15.—The lower posterior teeth are set against the occlusal arc guide.

of the same curvature as that of the teeth is placed so that it rests on the first bicuspids anteriorly and is pressed on the wax posteriorly until it approximates the middle of the retromolar pads (Fig. 14). The anterior teeth are disregarded in positioning the occlusal arc. Since many abnormalities exist, the operator must deviate from this method frequently, and use his own judgment in locating the posterior occlusal curvature.

With the occlusal arc in position, the remaining lower posterior teeth are placed in their proper position so that they are in line with the first bicuspids and are over the crest of the ridge. Their occlusal surfaces should be in perfect contact with the occlusal arc (Fig. 15).

The upper posterior teeth are set against the lower teeth with the articulator in a *lateral position* (not in a protrusive position). To maintain the articulator in a fixed lateral position, a metal insert is placed in the horizontal condylar guidance to prevent the condylar shaft from returning to the centric position. The lock nuts on the condylar guidances are tightened to keep the articulator in a fixed lateral position. The thickness of the metal insert used is determined by the extent of the functional range required.

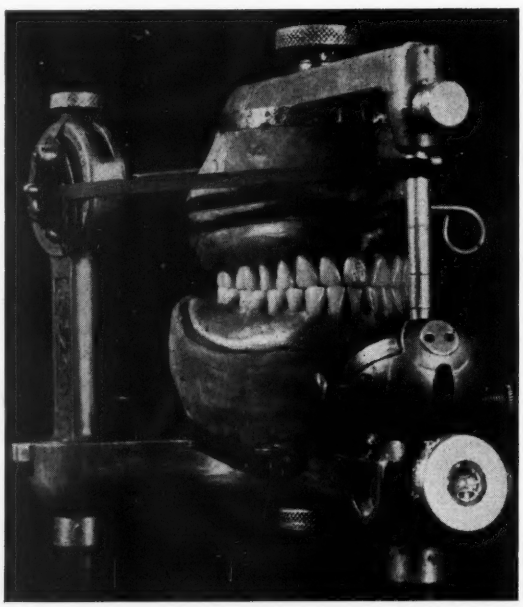

Fig. 16.—The upper right posterior teeth are set in working occlusion. The articulator is locked in a fixed right lateral position.

The metal insert is placed in the left horizontal condylar guidance, and the articulator is fixed in this position for arranging the posterior teeth on the right side in a right lateral position. The upper teeth are set against the lower teeth in a working occlusal relationship so the buccal edges of the upper teeth will be in line with the buccal edges of the lower teeth (Fig. 16). Care must be taken that the occlusal surfaces meet perfectly and that there is good lingual side contact. By setting the teeth in this position, lateral occlusal balance, correct working occlusion, and the proper posterior horizontal overlap in centric occlusion are automatically established.

Before setting up the left side, the balancing and protrusive occlusion on the right is checked. To do so, the instrument is locked in a fixed left lateral position, and then in a fixed protrusive position so that the balancing and protrusive contacts can be checked and corrected, if necessary.

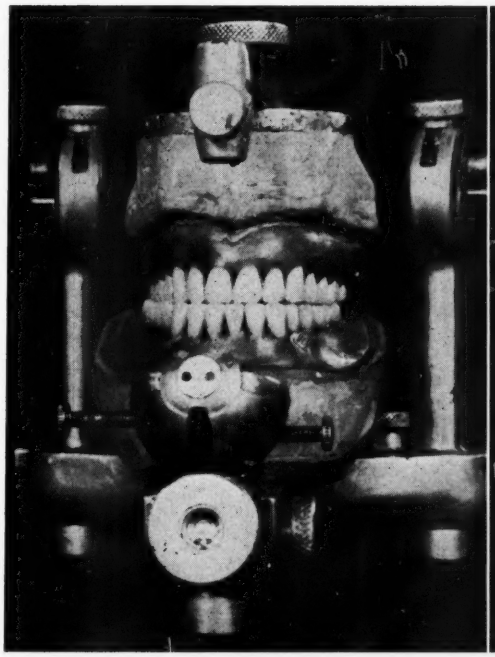

Fig. 17.

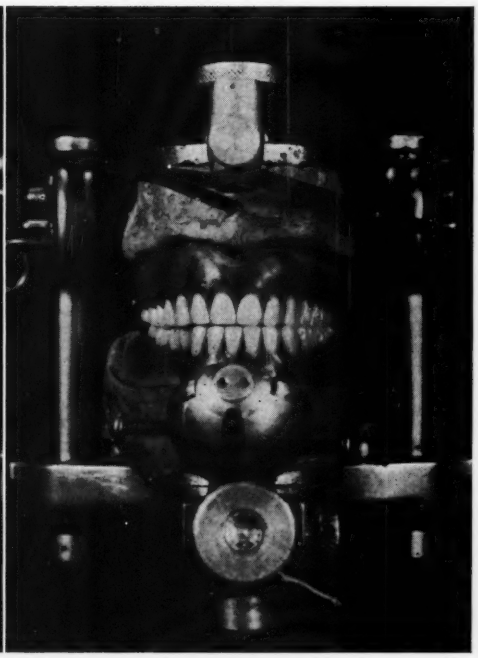

Fig. 18.

Fig. 17.—The completed set-up showing the occlusion in right lateral position.
Fig. 18.—The completed set-up showing the occlusion in left lateral position.

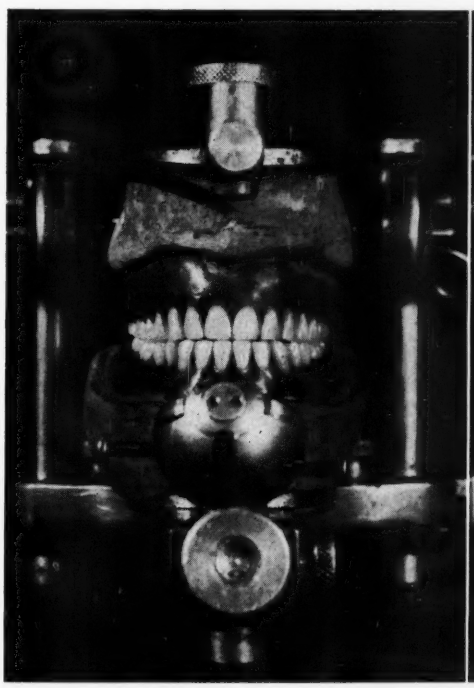

Fig. 19.

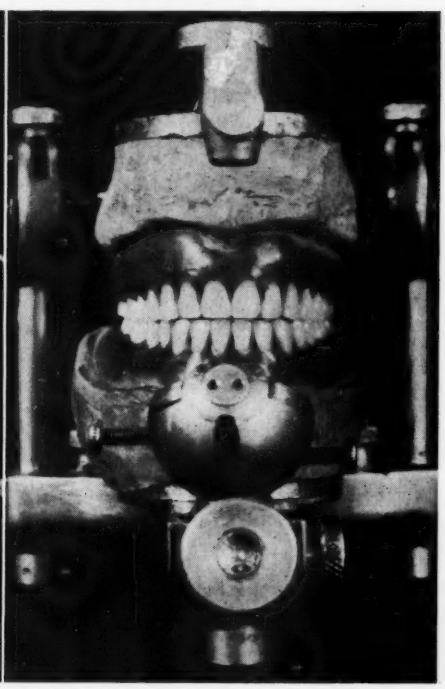

Fig. 20.

Fig. 19.—The completed set-up showing the occlusion in protrusive position.
Fig. 20.—The completed set-up in centric position.

The same procedures are followed for setting the teeth on the opposite side. When all the teeth are set up, the protrusive, right and left lateral positions are rechecked. Any premature contacts in the working, balancing, and protrusive positions are corrected. The final step is to check for premature contacts in centric position (Figs. 17, 18, 19, 20).

It is important to note that in the procedure outlined the upper and lower anterior teeth are set up according to the esthetic requirements. The principle of concentric curvatures of the same radius, however, is still followed since the anterior and posterior teeth are set up on coordinated concentric curvatures of varying radii. If the anterior and posterior teeth are placed on curvatures of the same radius, the upper anterior teeth would appear short and the lower anterior teeth long, thus presenting an unfavorable esthetic situation (Fig. 21).

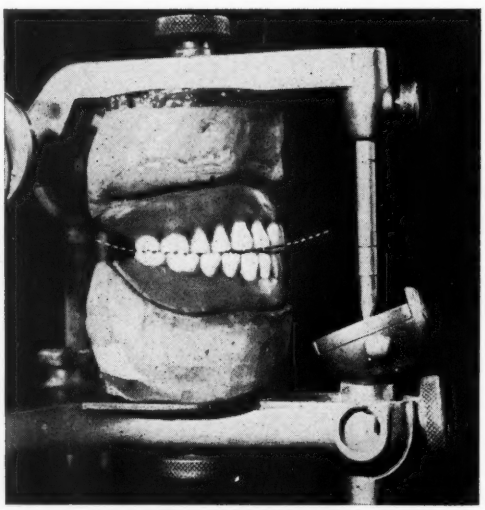

Fig. 21.—For esthetic reasons, the upper and lower anterior teeth are not set to the same curvatures as the posterior teeth. The dotted line indicates the curvature of the posterior occlusal surfaces.

SUMMARY

1. Both artificial cusp and flat cuspless occlusal forms present disadvantages when they are used for complete dentures.

2. Although the objectives of natural occlusion and prosthetic occlusion are the same, the aims of prosthetic occlusion must be achieved by mechanical means.

3. A cuspless occlusal pattern which incorporates the principle of concentric curvatures of the same radius is suggested as a means of accomplishing the aims of prosthetic occlusion in complete denture construction.

4. This cuspless occlusal pattern is characterized by a curved three-dimensional occlusal surface rather than by a flat, two-dimensional occlusal surface. It is bio-mechanical and meets with the biologic and mechanical requirements of occlusion in complete denture construction.

5. A simplified procedure for obtaining balanced occlusion has been described. The teeth are set to fixed lateral and protrusive positions, thereby obtaining proper working, balancing, and centric occlusion.

REFERENCES

1. Swenson, M. S.: Complete Dentures, ed. 3, St. Louis, 1953, The C. V. Mosby Co., pp. 237-338.
2. Wheeler, R. C.: Textbook of Dental Anatomy and Physiology, Philadelphia, 1940, W. B. Saunders Co., pp. 350-364.
3. Landa, J. S.: Practical Full Denture Prosthesis, Brooklyn, 1943, Dental Items of Interest Publishing Co., pp. 183-199.
4. Craddock, F. W.: Prosthetic Dentistry, ed. 2, St. Louis, 1951, The C. V. Mosby Co., p. 218.
5. Little, A. P.: Practical Bio-engineering in Full Denture Construction, J.A.D.A. **22**:1016-1028, 1935.
6. Sears, V. H.: What Is the Future Status of Non-anatomic Posterior Tooth Forms in Full Denture Prosthesis? J.A.D.A. **18**:662-671, 1931.
7. Sears, V. H.: Thirty Years of Nonanatomic Teeth, J. Pros. Den. **3**:596-617, 1953.
8. Boucher, C. O.: Occlusion in Prosthodontics, J. Pros. Den. **3**:633-656, 1953.
9. Fish, E. W.: Principles of Full Denture Prosthesis, ed. 4, London, 1948, Staples Press, p. 14.

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THE ROLE OF CEPHALOMETRICS IN PROSTHETIC DIAGNOSIS

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THE SUCCESS OR FAILURE of increasing the occlusal vertical dimension may be closely related to the shape of the mandible. The degree of posterior extension of an upper denture may depend upon the form of the base of the skull which is thought to influence the angulation of the soft palate. The stability of the lower denture is frequently dependent upon the size and function of the tongue or length and actions of the lips. Degeneration of the temporomandibular joint can be caused by the loss of posterior teeth and by arch irregularity.

Factors such as these illustrate the need for a more basic concept and rational approach to the management of prosthetic and reconstruction cases. This article proposes to demonstrate the use of a "new" tool or weapon in the available armamentarium of the prosthodontist—namely the use of cephalometric roentgenography.

Prosthetics has come a long way from the early "mush bite" technique employed for the registration of the maxillomandibular relationship. The most recent methods consist of precise extraoral tracing procedures, "chew in" techniques, or of location of the terminal hinge axis of the mandible. Currently, the duplication of all the movements of the mandible with a mechanical instrument is a general objective of many clinicians. This achievement is thought to make possible the arrangement of artificial teeth to a balanced relationship with the mechanical workings of the individual jaw. On the other hand, flat planes and flat cusps are considered most desirable by another school of thought.

Vertical dimension has been another controversial issue. Generally, the height of the denture has been determined by speech or phonetics or from the personal opinion of that which "looks good." An equally nebulous rule of facial proportion has also been sometimes employed.

Certain planes or points of the face and skull have been used for orientation of the denture. The eye-ear plane, or Frankfort plane, and the ear-nose plane, or Camper's plane, has been employed for reference. The most common practice has consisted of relating occlusion rims to the lip line and to the retromolar area of the mandibular cast. Few real objective criteria have been made available for the evaluation of proper occlusal vertical dimension, location, and inclination of the level of the occlusal plane.

Presented as a part of a Temporomandibular Joint Symposium before the Joint Session of the American Denture Society and the Pacific Coast Society of Prosthodontists, San Francisco, Calif., Oct. 15, 1955.

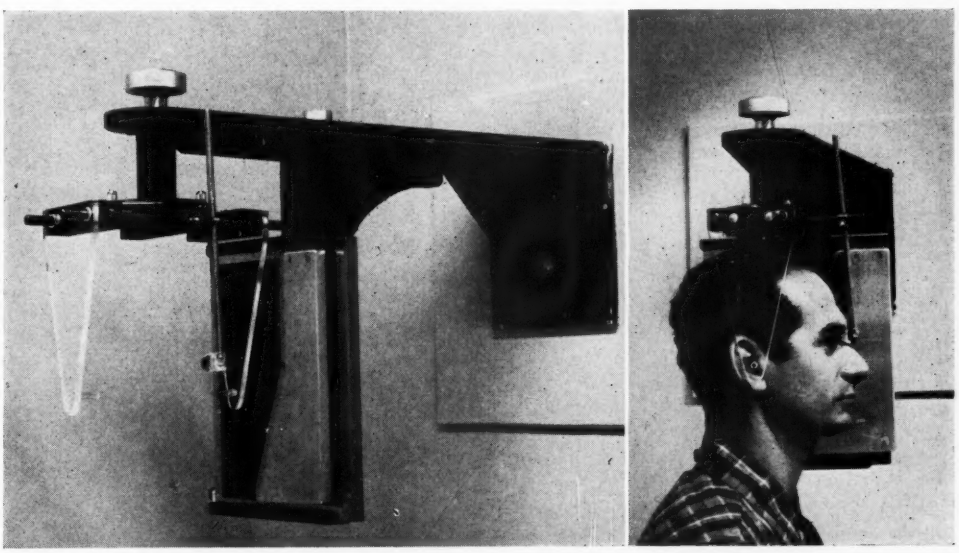
This article was commissioned by the Editorial Council of the JOURNAL OF PROSTHETIC DENTISTRY upon the suggestion of the Program Chairman.

Received for publication Dec. 13, 1955.

Greater understanding of the problems and more agreement on treatment may result from better means of visualization. From cephalometrics, information has been derived to classify the anatomic relationships[1,2] and to determine the physiologic conditions of the structures of the head and neck. More important however, cephalometrics has revealed the changes induced by treatment and served as a record to evaluate the ultimate success or failure of treatment objectives years later.

THE HISTORY OF CEPHALOMETRICS

It is important to note that cephalometrics was reported in 1930 almost simultaneously by Broadbent,[3] an orthodontist, and Hofrath,[4] a prosthodontist. Although the methods were called by different names, both consisted of obtaining a true lateral roentgen-ray image of the head, capable of duplication at a later date. The differences noted in the subsequent roentgenograms were, therefore, true differences in the patient and not errors in roentgenographic technique.



A. *B.*

Fig. 1.—*A*, A head-holding apparatus. Note the automatic centering ear rods and nasion rest. The cassette is adjustable in two directions. The aluminum filter plate brings out the soft tissues of the face. *B*, Patient in the head holder and the film in position. The higher kilovoltage machines are very satisfactory.

Broadbent's idea was mainly to provide a method to measure facial growth changes, while the objective of Hofrath was to evaluate the results of prosthetic reconstruction. A great deal of information has been gleaned from cephalometrics by orthodontists, while the investigations by those interested in prosthetic reconstruction have been fewer and less objective in theme.

THE CEPHALOMETRIC PROCEDURE

A great many head-holding devices are on the market today. For the most part, they consist of a pair of ear rods with an automatic head-centering arrangement, and a provision to hold the cassette. One such simple device is seen in Fig. 1. The cephalometric technique is not difficult. The resulting films obtained

in such a manner are easily discernible. The right and left sides can be selected on the basis of greater enlargement of the patient's side farthest from the film. Even laymen can be taught to locate the necessary structures for purposes of orientation.

In order to interpret the roentgenogram in any detailed manner, a tracing is made on acetate paper to include the outline of hard and soft structures and the location of landmarks. Using cranial planes for references, tracings of subsequent films can be superimposed in series to show the actual changes that have occurred. Fig. 2 shows tracings of head films of a complete normal dentition patient and an edentulous patient, with certain points and planes noted.

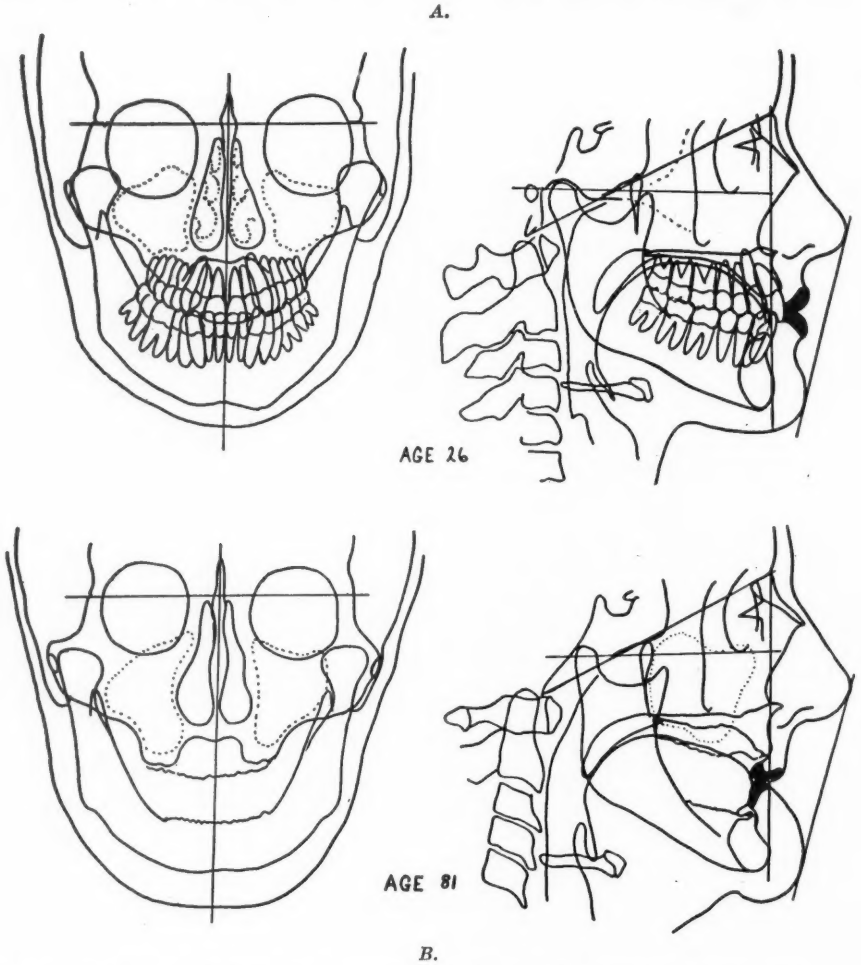


Fig. 2.—*A*, Tracings of frontal and lateral head films of a 26-year-old patient with a normal occlusion. Note the various structures traceable on the films. Note the symmetry of the head and well-formed mandible in the frontal tracing. Structures noted in the lateral tracing include the hard structures in addition to the nose, lips, tongue, soft palate, throat walls, and pharynx. *B*, An 81-year-old edentulous patient. The frontal film reveals extremely large sinuses. The lateral film reveals arthritic changes in the cervical vertebrae but still a good form and proportion to the face. Note the collapse of the mouth. The patient had worn dentures for 30 years. Note the irregularity of the hard palate. The elevation is possibly due to a depressed area in the denture.

Two simple planes or lines that can render important information are the Frankfort plane and the facial plane. Two very simple angles employed for the cephalometric analysis are the facial angle and the angle of convexity. In faces exhibiting almost perfectly arranged teeth, faces are noted to approach a right angle when the facial plane is related to the Frankfort plane. Cases more than 10 degrees below a right angle are suggested to be mandibular deficiencies while those greater than 90 degrees border on mandibular prognathism. By relating the frontonasal suture to the anterior portion of the maxillae and to the chin, a measure of convexity or concavity can be visualized. In most normal conditions, the face approaches a straight line. Extremes in either direction can be quantitated.

Tracings in the frontal head plate reveal the symmetry of the face and the general characteristics of squareness or length to the face and suggest mandibular types. An interpretation of both views give a clearer definition of the morphologic conditions involved.

PHYSIOLOGIC CONSIDERATIONS OF THE HEAD

In addition to facial morphology an impression can be gained of the various muscle conditions by viewing the soft tissues in the roentgenograms. The environment of the denture is created by the arrangement of musculature on the bony framework of the face and base of the skull or brain case. The environmental factors can be visualized best in three muscle systems of the head and the neck. Fig. 3 represents these systems.

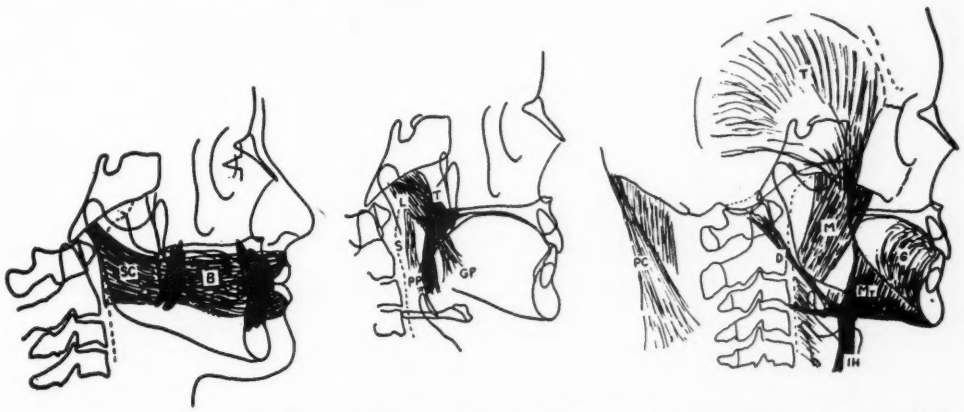


Fig. 3.—The pertinent muscles of the head and neck can be visualized in three systems. Note the superior constrictor and buccinator muscles arranged horizontally and encircling the denture. The soft palate muscles are arranged to function vertically. Note the position of attachment of the levator (*L*) muscle at the center of the soft palate which hooks the soft palate during speech as it is held downward at the posterior by the pharyngeal muscle. (*PP* pharyngopalatinus). Note that the third system includes the muscles of mastication and is related to the postural postcervical muscles. The tongue is also included in this system. *A*, Throat-cheek lip system (horizontally displayed); *B*, soft palate (vertically arranged); *C*, posture-mastication-hyoid-tongue complex (chainlike relation).

The first system, that which is displayed in almost a horizontal manner, is the superior constrictor, buccinator lip complex. When viewed in this manner it can be seen that the mouth, the cheeks, and the pharynx form one complete integrated sphincterlike arrangement. This muscle system constricts and is the

limiting factor in the molding of the arch of teeth. It can be seen to extend from the lips to the posterior throat wall and to the base of the occipital bone.

The second system of musculature is that of the soft palate and the lateral throat walls. This system can be visualized as functioning in almost a vertical manner. The elevator of the soft palate, being attached near its middle, hooks the soft palate in an upward and backward direction as the end of the soft palate is held downward by the pharyngeal musculature. In speaking, the soft palate is elevated and, in swallowing, the soft palate serves as a plunger for driving food into the pharynx.

The third system of musculature can be thought of as links in a chain. This chain starts from in back of the head, in the postcervical muscles which support the head in the upright position, and circles the head, coming into the temporalis, the masseter, and the superior and inferior hyoid muscles. In this arrangement the face is supported in a cantilever fashion with the mandible, the tongue, and the pharynx operating in an elastic chain. As one muscle is stretched, the remaining muscles take up the slack to maintain stability of the system. An appreciation of this chainlike function can be gained by observing the acts of chewing, swallowing, and speaking in cinemafluoroscopy. The role of the tongue should not be overlooked in this arrangement, for it, too, serves as a plunger; opposing the lips and cheeks on the outside, it serves as the molding influence for the dental arch from within.

When the mandible is viewed in this manner, it is seen to occupy its place in the muscle system. In the act of deglutition it serves as support for the tongue, for the hyoid musculature, and muscles of the pharynx. This support is also vital to the function of respiration whereby the mandible serves to maintain the airway through its support to the tongue and the muscles of the larynx. It, therefore, must be remembered that the purpose of the mandible is not merely for the support of teeth. Factors other than those concerned with the teeth must be considered when dealing with mandibular relationships.

FINDINGS ON FACIAL VARIATIONS

As stated before, the muscle systems of the head and neck are arranged and draped on a skeletal framework. Variations in that framework, therefore, influence to a large degree the direction and effect of the muscles involved. Fig. 4 illustrates certain types of faces that can be observed in regular clinical practice.

It will be noted that retrognathic-type faces are characterized by a small mandible or by a mandible that is located posteriorly in the cranial base. This yields high convexity to the profile (Fig. 4,*A*). Large mandibles combined with small maxillae produced severe concavity to the facial outline (Fig. 4,*B*). These conditions represent a disharmonious relation of the basal bones. However, the alveolar process and teeth can also contribute to disharmony at the mouth. Fig. 4,*C* demonstrates a maxillomandibular protrusion. Primary alveolar protrusion of the upper arch in a fairly good skeleton is represented in Fig. 4,*D*.

Wide gonial angles of the mandible together with long mandibular bodies carry the chin far downward and contribute to "open bite" (Fig. 4,*E*). On the

other hand, overly developed angles are seen to be more consistent with short faces. Strong, powerful closing muscles contribute to deep vertical overlap and resist the increase of the occlusal vertical dimension by any means other than tooth depression (Fig. 4,*F*).

A comparison of *E* and *F* in Fig. 4 causes skepticism as to the use of facial proportions for the establishment of vertical dimension of the denture. Both are almost exactly the same measurement in the upper face, but they differ almost 3 cm., or more than 1 inch, in height of the lower face. (More than 10 per cent of total facial height.)

In each of these instances, extreme variation can be seen in the tongue, the lips, and the soft palate. In addition, differences in the physiology of the muscles of mastication are suspected on the basis of form and relation of the facial bones.

The tongue can be seen to occupy the entire oral cavity in some cases. In combination with loose or flaccid lips the tongue produces the protrusive effect

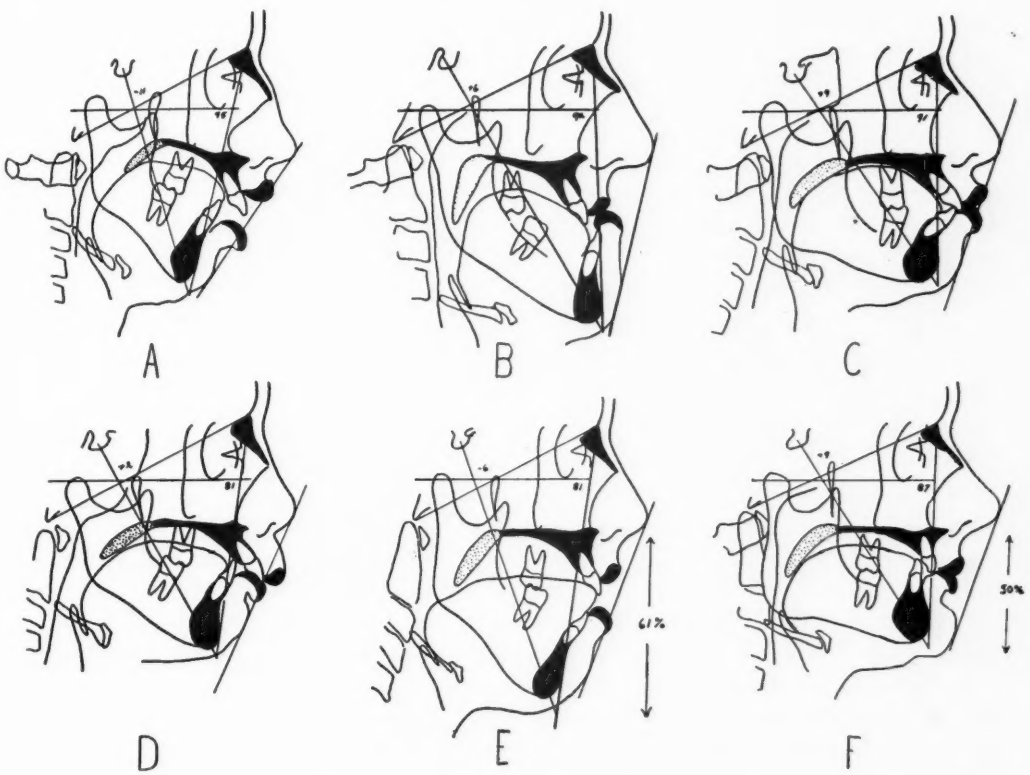


Fig. 4.—Variation of patients with facial disharmony. *A*, A retrognathic pattern—note the short mandible, the high condyle, and angle of the hard palate. This arrangement yields high convexity. *B*, Note the prognathic mandible and concavity of the face. *C*, Note the maxillomandibular protrusion and the position of the tongue and lips to contribute to the disharmony. *D*, Note the extreme protrusion of the upper teeth in spite of the fairly good facial pattern and long lips. *E*, Note the long face, low tongue, and "open bite." The mandibular body lies well inclined vertically and the lips are short. *F*, Note the short face, the retracted denture and the "closed bite." Note that the mandibular border lies almost horizontally.

seen in Fig. 4,*C*. When a small tongue is found together with tight lips in the same type of face, the deep vertical overlap and retracted denture results as seen in Fig. 4*F*. On the other hand, mandibular prognathism carries the tongue downward away from the maxillae and contributes to the collapse of the maxillary arch of teeth (Fig. 4,*B* and *E*). "Open bites" occur in such instances as a result of jaw form and tongue position (Fig. 4,*E*).

In addition to lip tonicity, as just mentioned above, the length of the lips may vary considerably. Fig. 4,*A* and *E* both illustrate short lips while Fig. 4,*D* demonstrates long lips.

In these instances also, the angulation of the soft palate from the palatal plane varies dramatically.[5] In cases exhibiting a narrow nasopharynx with a great amount of length to the cervical vertebrae, the soft palate is seen to lie almost directly vertically (Fig. 4,*B*). Conversely, faces exhibiting great depth together with shortness of the neck influence the soft palate to lie in almost a horizontal manner (Fig. 4,*C*).

Therefore, it seems apparent and important that functional variation is implicit with certain variations in the form of the face and the relationship of the skeletal parts.

THE REST POSITION CONCEPT

Although the phenomenon of physiologic rest position of the mandible was not new with Thompson,[6] he must be given credit for its explanation on certain physiologic principles. By studying serial cephalometric head roentgenograms of growing children, and by studying a series of patients receiving artificial dentures, Thompson concluded that the physiologic rest position of the mandible was constant. He postulated that the mandible was suspended in the chainlike arrangement of musculature described above, and was therefore positioned by muscle tonus. Being a part of the posture system, when at rest, the mandible was not thought to be influenced by the presence or absence of teeth. In closing from rest position, the mandible was noted to move upward and forward through a distance of 2 to 3 mm., with the point of rotation near the center of the condyle. When malposed teeth interfered with the normal path of closure, the mandible could be deflected, and the condyles were thought to be displaced from their correct position. Previous studies by Hildebrand[7] had indicated that the mandibular position in occlusion was dictated by the teeth.

Following these significant findings, the analysis of occlusion came to be made from the resting position of the mandible. Patients requiring rehabilitation were oriented to the rest position, many with good success. However, some patients were noted in whom the interocclusal dimension or free-way space was excessive, and which in closing moved upward and backward without being dictated by tooth interference. These observations lead to a search for other factors that should be considered in the rest position concept.

LAMINAGRAPHY

The cephalometric head film does not permit a visualization of the condyle fossa relationship because of the superpositioning of the dense structures of the

petrous portion of the temporal bone; also the usual temporomandibular joint roentgenographic technique does not include a clear lateral view of the mandibular condyle that is free of distortion nor include an area large enough for orientation of the mandible and the denture together.

The method of laminagraphy permits the visualization in a prescribed plane of parts otherwise obscured by dense structures. Hence, a lamina or layer or a body section likened to a histologic section is made of the predetermined area (Fig. 5). Application of the same cephalometric techniques to laminagraphy provided a true lateral image of the condyle and fossa, capable of being measured, and included the denture and the joint simultaneously. Laminagraphy was, therefore, the method of choice for a controlled investigation of the temporomandibular articulation.

Fig. 5.—A laminagraph section of a normal temporomandibular joint. Note the smooth surfaces of the condyle and eminence and the well-centered condyle. Note the true lateral view and the dentition visible with the joint on the same film.

In the studies of functional variation,[8-11] a point of rotation near the condyle was verified; however, this point appeared to be slightly lower than the center of the condyle (Fig. 6). In about 15 per cent of the "normal" cases, some translatory movement was noted from rest to closure. These were not thought to be deflections of the mandible as a result of tooth interference.

In patients with deep vertical and horizontal overlaps of the teeth, the mandibles were revealed to move in a more distal direction from rest to closure. It was found that the condyle position in occlusion was normal in these patients, and that the condyle position at rest was downward and forward. Consequently, the physiologic

rest position was concluded to be unreliable for orientation of tooth occlusion—when factors were present to influence that position to be abnormal. Since the abnormal rest position was noted primarily in Class II malocclusion cases, the deep vertical and horizontal overlap of the teeth were thought to influence the rest position in an indirect manner.

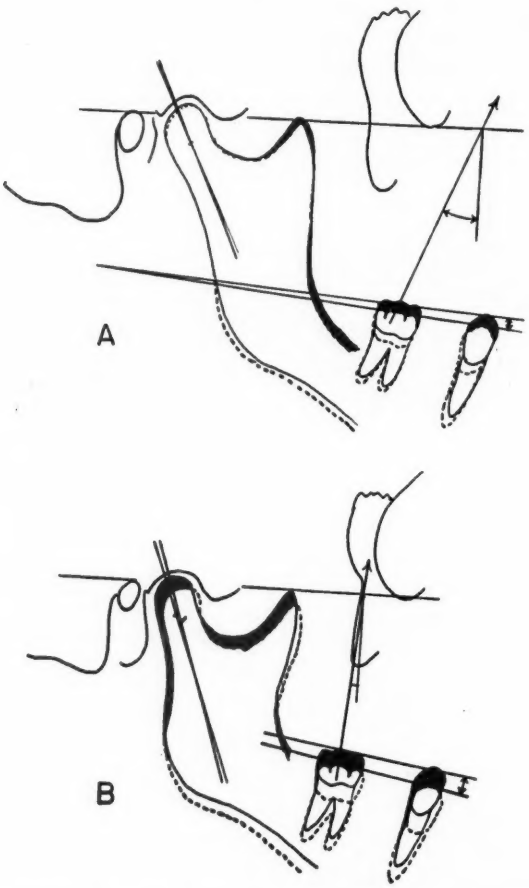


Fig. 6.—*A*, The average behavior from rest to closure in 50 "normal" cases. Note the point of rotation at the neck of the condyle, the upward and forward direction of movement, and the 2 mm. interocclusal dimension. *B*, Note the difference in behavior of Class II cases with deep vertical or horizontal overlap. Note the translatory movement of the condyle, the vertical path of closure, and the wider interocclusal dimension.

In addition to variations from rest to closure, differences were noted in the opening movement. For instance, short mandible cases were noted, in which, in the initial stages of opening, the condyle was thrust forward. In cases of prognathism, the mandible was observed to rotate during the initial phases of opening only to come forward in the final stages of mouth opening. Fig. 7 indicates the differences in the path of opening of the mandible as observed by superpositioning the tracings of the two cases. Therefore, variation in function was considered to be an adaptive process to the skeletal pattern.

DISCUSSION OF PHYSIOLOGY OF THE MANDIBLE AND THE TEMPOROMANDIBULAR JOINT

In the discussion of function of the mandible, it should first be realized that the consciousness of the mandibular position is attained through the function of the proprioceptive system. Sensory impulses are received through tiny nerve fibers around muscle bundles, from the periostium of bone, from the periodontal membrane of the teeth, and from the ligaments and capsule of the temporomandibular joint. The harmony and synchronization of activity, therefore, is provided through the adaptation of the neuromuscular system. The teeth serve as guides for the final positioning of the mandible through this process.

A basic principle involved at this time is that the mandible behaves under the concept of conservation of energy and conservation of tissue. Its architecture is of such a nature that little motion or energy is wasted. Muscles tend to achieve a maximum benefit with a minimum effort. The mandible serves in all such functions as mastication, incision, speech, deglutition, and respiration. In addition, it is a part of the face, and psychologic states are reflected in its behavior pattern. Therefore, a consideration of all these functions is necessary when analyzing the rest position.

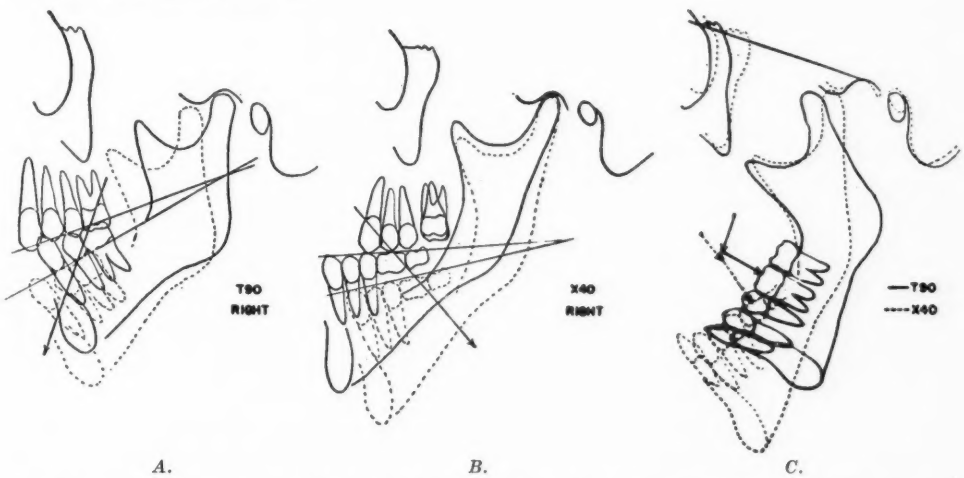
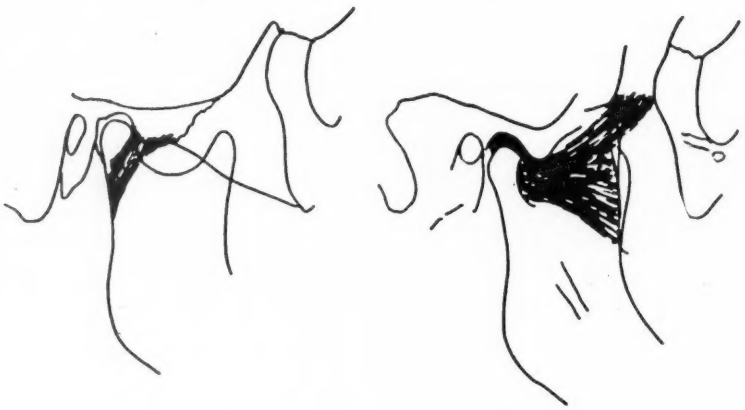


Fig. 7.—Variation in the path of opening in different facial patterns. *A*, A Class II case one-half open. A short square mandible. Note the initial forward movement of the condyle during opening. *B*, A Class III case one-half open. Note the predominant rotation during the initial phases of opening in the long mandible case. *C*, Both cases wide open. Note the difference in the path of the lower molar in the two cases.

Under such a concept it seems only logical that the mandible would simulate a convenient or neutral position for the many functions it is called upon to serve. Hence, it assumes the downward and forward position in the adaptive and conservative process to accommodate to excessive horizontal overlap, to open the airway, and to adjust to abnormal skeletal patterns. It should be remembered, however, that in cases of normal harmonious relationship of all parts, it still represents a good position for orientation. Also, it will remain constant so long as all factors remain constant. But, given a dramatic change in any of the parts, a change in the rest position will be probable.

At various times throughout the literature a great deal of significance of the temporomandibular joint behavior has been placed in the ligaments of which there is only one of great importance. This is the lateral ligament. It should be pointed out that ligaments, like connective tissues, cannot withstand a permanent stretch (Fig. 8). It is true that they are checkers and restrainers of the joint, but the permanent stability of any joint is ultimately obtained by the musculature.



A. *B.*

Fig. 8.—*A*, The lateral ligament is a checker and restrainer. *B*, The external pterygoid muscle stabilizes the condyle.

In the function of any joint there is a stabilizing and a mobilizing component. The joint is stabilized in the sense that the forces of gravity are overcome, and in the sense that the limb is fixed in a position so that motion of the rest of the structure can be obtained. The most important muscle to be considered in the stability of the temporomandibular joint is the external pterygoid. This muscle being attached at almost right angles to the condyle, holds the condyle in juxtaposition with the articular disc and with the eminentia. Since this muscle is displayed in an almost horizontal position, it is opposed almost directly by the posterior fibers of the temporalis muscle. These muscles combine to render the stability of the joint. However, the external pterygoid also plays a large role in movement of the condyle. It is the protruder of the mandible and is of extremely great importance in the opening of the mandible.

During the act of chewing, this muscle in conjunction with the guiding influences of the teeth, and together with the condylar disc and the articular eminence, forms the unit of related structure in the masticating apparatus. A thorough study of the external pterygoid muscle is suggested for those wishing a full appreciation of the function of the temporomandibular joint with all its ramifications. In practically all cases of joint disturbances, the cause can be traced to the abnormal behavior of the muscles.

JOINT DISTURBANCES CAUSED BY MALOCCLUDED CONDITIONS OF THE TEETH

In the study of any structure of the body we learn how the normal should behave by determining the factors producing pathology. In other words, we learn the normal through the study of the abnormal.

In condensing the histories of more than two hundred pathologic joint conditions, it appeared that distinct types of joint disturbances could occur as a result of four distinct conditions of the teeth and jaws.

The first type (Fig. 9,*A*) is that of excessive range of function of the condyle. This type occurs primarily in patients with a severe horizontal overlap malocclusion, in which the condyle is called upon to function almost at the summit of the eminence or beyond, for the function of incision and for speech. Prolonged function in this anterior position has led to resorption of the articular surface of the condyle in some cases. It appears, therefore, that the condyle was not intended to function at the summit of the eminence for the usual act of chewing and for speaking.

The second type of disturbance is that seen in posterior condylar displacement cases or those with a distal thrust (Fig. 9,*B*). In these conditions, the influences of the teeth wedge the condyle deep into the fossa and produce a trauma at the posterior border of the condyle. In addition, the articular disc is sometimes thrown forward and the juxtaposition of the condyle with the eminentia is lost. These conditions account for the greatest amount of clicking observed in the author's experience. Based on this pathologic entity, it appears that the most posterior or retruded position of the condyle that can be obtained is not in keeping with the normal functioning joint.

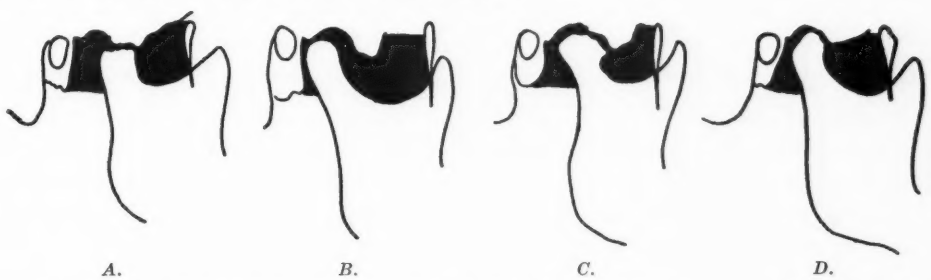


Fig. 9.—Pathologic joints. *A*, Excessive range of function and prolonged function in the forward position; *B*, distal displacement; *C*, interference; *D*, loss of posterior support.

The third type of joint disturbance is that seen in interference conditions (Fig. 9,*C*.) The supraeruption of a lower third molar is the best example of this condition. As the mandible moves forward, it tends to rock on an overerupted molar, thereby dislodging the condyle and producing trauma in the joint. This is perhaps the most easily corrected joint condition. Simple removal of the tooth or grinding down the interfering structure will lead to dramatic improvement.

The fourth type (Fig. 9*D*) is perhaps the type the prosthodontist most frequently will be called upon to treat. This is the condition of loss of posterior support, usually through the loss of posterior teeth. Laminagraph roentgenograms have clearly indicated that the condyle in such instances is thrown upward, or

upward and forward, against the eminence to a degree in which the duration of the force involved has been great enough to erode both articulating bodies. The normal joint is designed to take intermittent stresses, particularly of the gliding nature that it usually encounters. However, with the loss of posterior teeth, the stress is increased in both time and amount. In cases wherein the tolerances of the joint are overcome, a pathologic entity of degenerative joint disease ensues. This is degenerative arthritis in the true sense of the word. Isolated cases have been observed in which this degeneration has proceeded down the neck of the condyloid process. Based on these pathologic cases, it appears that a full complement of teeth is important to the normal functioning joint. It also appears that function in the molar area is significant.

DISCUSSION

When used in the proper manner, cephalometrics can be a useful tool to the prosthodontist. Each face has its own characteristics and these can be classified by the application of cephalometric procedures. A clear definition of the basic structures of the jaws and the base of the skull is available in the head film. The teeth can be related to the bony framework of the face in all dimensions. The relationship of the lips, the tongue, the soft palate, the throat walls, and the hyoid bone can all be evaluated and correlated to the various occlusal problems. In addition, many functions of the mandible can be measured. The interocclusal dimension or the free-way space can be determined. The rest position of the mandible has been postulated to be of clinical significance. Even though the clinician does not subscribe to prevailing theories, cephalometrics is a tool whereby he can evaluate his own technique and treatment philosophy. The clinical use of cephalometrics should lead to better treatment prescription and prognosis for the individual. However, cephalometrics is weakened by the fact that the temporomandibular joint is obscured in the head film.

It may be wondered why the omission of one structure should be of so much concern. Is this area really that important? In order to answer this question, it is necessary to review the entire purpose and reasons for the existence of this joint. In other words, just why is this joint there and what does it do?

Probably the greatest contribution of this joint is the growth of the condyle. Without growth activity of the condyle we have little left that even resembles a normal mandible. During the active growth span, growth of the condyle predominates over everything else as nearly as can be determined. A second contribution in this joint is the provision for maintenance of the airway. During mouth openings the condyle is brought forward to prevent impingement of the chin and tongue against the cervical vertebrae. The third purpose of the joint is its role of guiding influence to movements of the mandible in chewing. It should be pointed out that, in this sense, in the normal dentition, it serves to disarticulate a portion of the teeth while action and energy is directed to other sections of the dentition. In the edentulous condition the guiding influence must be considered even more in view of the need for bilateral functional contact in order to promote denture stability.

These reasons lead to an appreciation of the temporomandibular joint for its true value. Laminagraphic studies of the joint have contributed to our knowledge concerning the normal and the abnormal. As shown previously, pathology of the joint was noted when the condyle was abnormally located in the fossa for a prolonged period. The normal temporomandibular joint is characterized by a condyle that is well formed and well centered in the glenoid fossa (Fig. 10). The con-

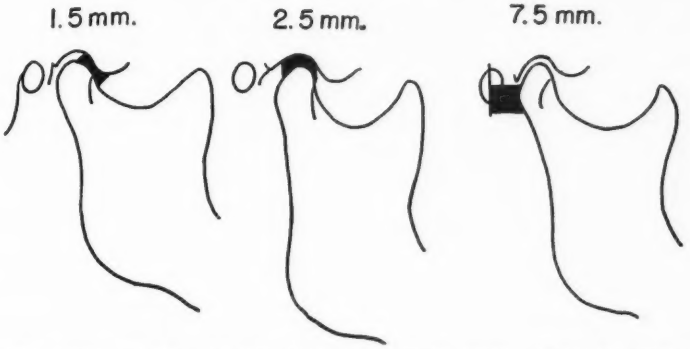


Fig. 10.—The mean condyle location in 100 "normal" cases. Note the well-centered position and smooth articular surfaces. *A*, Condyle-eminence; *B*, condyle-fossa; *C*, condyle-meatus. (From Ricketts, Am. J. Orthodontics, June, 1955.)

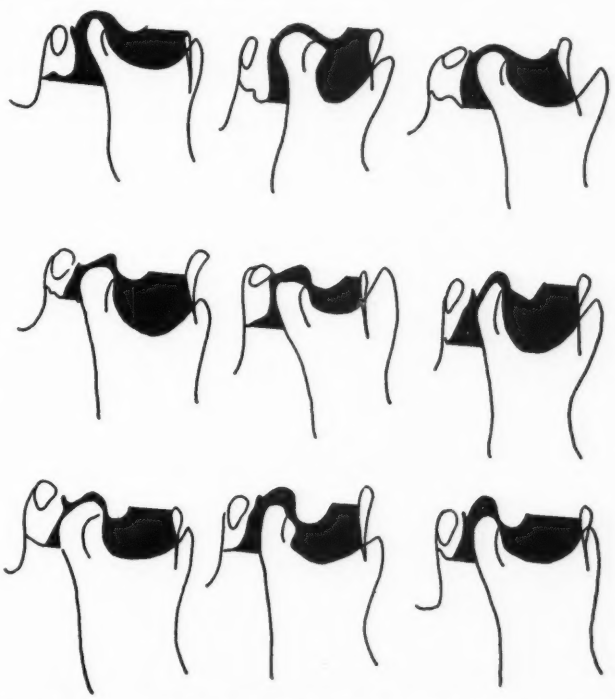


Fig. 11.—The range of variation of morphology of the joint structures. *A*, Large shallow fossa. Note the variation of the condyle in shallow fossae and the small condyle in the upper left. *B*, Small fossa. Note the differences in condyle form and position in cases with small fossae. Note the short neck in the center figure and the long narrow neck in the right center figure. *C*, Deep fossa. Note the large condyle in the left figure. Note the downward and forward position of the condyle in the lower right figure. (From Ricketts, Am. J. Orthodontics, June, 1955.)

dyle and the articular eminence are smooth in contour. The articular disc travels downward and forward together with the condyle during normal opening and protrusive movement. When all structures are in good balance and harmonious relationship, the resting condyle should also be in the well-centered or "centric" position. From this central position of the condyle, the chin point should rotate upward and forward through an arch of 2 to 3 mm. to the fully occluded position of the teeth without deflection or without interference by the teeth.

It appears that this ideal relationship is truly something to be sought in treatment. However, in view of the great variation in all the structures involved, and the accompanying neuromuscular adaptation, a latitude from this conceived ideal should be realized (Fig. 11). In treatment, it is important to determine the possible contributing factors and instituting care according to the individual conditions. (Note the morphologic variation of the joint in Fig. 11.)

The need for dental prosthesis arises most frequently in the middle or later years of life following the gradual loss of teeth and improper chewing patterns. These have often been progressive, and sometimes irreversible situations are present as a result. In treatment, therefore, it may be asking too much of the patient to adhere to a fixed conception of the ideal. Therefore, the philosophy of a continuous vigilance toward the ideal is sound. Under such an orthopedic philosophy, it may take many attempts to reach the ideal if that is ever possible.

It is, therefore, important that a cephalometric record be obtained so that treatment procedures can be evaluated, and that the changes that occur after treatment and through the dimension of time can be recorded. The success or failure of treatment procedure after years of wear can thus be evaluated.

It is clearly evident that the interest of the dentist should not be limited to the teeth and mastication alone. The functions of speech, respiration, posture, and psychosomatics are equally important considerations. A better interpretation of all of these functions can be obtained through cephalometric procedures.

Large-scale controlled cephalometric and laminagraphic studies have not been conducted on prosthetic patients. No statistical evidence is available for the determination of the most satisfactory position of artificial teeth in the different facial types and patterns. Success or failure has not been analyzed in terms of the relationship of basal bones, the influences of the lip and tongue, and the many physiologic considerations of the mandible. The variety of treatment techniques and mechanical theories can and should be investigated. These are prosthetic problems and the answers should be sought by prosthodontists.

SUMMARY

1. Observation from research in cephalometrics as directed or applied to prosthetics has been presented.

2. Correlations with these findings to laminagraphic studies of the temporomandibular joint were made.

3. A biologic and physiologic approach to prosthetic diagnosis has been outlined.

REFERENCES

1. Downs, W. B.: Variations in Facial Relationships: Their Significance in Treatment and Prognosis, Am. J. Orthodontics **34**:812, 1948.
2. Downs, W. B.: The Role of Cephalometrics in Orthodontic Case Analysis and Diagnosis, Am. J. Orthodontics **38**:162, 1952.
3. Broadbent, B. Holly: A New X-Ray Technique and Its Application to Orthodontia, Angle Orthodontist **1**:45-66, 1931.
4. Hofrath, Herbert: Die Bedeutung der Roentgenfern—und Abstandsaufnahme fur die Diagnostik der Kieteranomalien, Fortschr. Orthodont. **1**:232-258, 1931.
5. Ricketts, R. M.: The Cranial Base and Soft Structures in Cleft Palate Speech and Breathing, Plast. & Reconstruc. Surg. **14**:1, 1954.
6. Thompson, John R.: The Rest Position of the Mandible and Its Significance to Dental Science, J. A. D. A. **33**:151-180, 1946.
7. Hildebrand, G. Y.: Studies in the Masticatory Movements of the Human Lower Jaw, Skandinavisches Archiv. fur Physiologie, Supplement zum 61.
8. Ricketts, R. M.: Variations of the Temporomandibular Joint as Revealed by Cephalometric Laminagraphy, Am. J. Orthodontics **36**:877-898, 1950.
9. Ricketts, R. M.: Various Conditions of the Temporomandibular Joint as Revealed by Cephalometric Laminagraphy, Angle Orthodontist **22**:98-115, 1952.
10. Ricketts, R. M.: A Study of Changes in Temporomandibular Relations Associated With the Treatment of Class II Malocclusion, Am. J. Orthodontics **38**:918-933, 1952.
11. Ricketts, R. M.: Laminagraphy in the Diagnosis of Temporomandibular Joint Disorders, J. A. D. A. **46**:620-648, 1953.

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A CEPHALOMETRIC STUDY OF THE CLINICAL REST POSITION OF THE MANDIBLE

Part I. The Variability of the Clinical Rest Position Following the Removal of Occlusal Contacts

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WHEN MAN ATTEMPTS TO measure a physiologic process, he usually is confronted by variability from one human being to another, and by variability in the same human being from one examination to another. Each physiologic process has a range of variability which is compatible with health. If this range is exceeded, the individual becomes sick, and the physiologic state becomes a pathologic state.

Moreover, each physiologic process has a range of variability which is characteristic for that process. For example, the range of variation of blood pH is very small, whereas the range of variation for body weight is greater.

Man's ability to detect this variability depends on: (1) the accuracy and validity of his measurements, (2) the number and timing of his measurements, and (3) the degree of variability of the physiologic process.

The so-called rest position of the mandible is generally considered a physiologic state established by the balance of antagonistic muscle forces. Our ability to detect a variability of the rest position depends on: (1) the accuracy and validity of our measurements of the rest position, (2) the number and timing of our measurements, and (3) the variability of the rest position.

The Accuracy and Validity of Measurements of the Rest Position.—The obtaining of accurate measurements of the resting vertical dimension by the usual clinical means is hampered by the following disadvantages: (1) The measurements are made on soft tissues. (2) Manipulation about the face is necessary at the moment of measurement with measuring devices. (3) The concentration is on the measuring device instead of on the patient. (4) The lack of permanent record and of permanent reference points to return to at subsequent examinations.

The advantages of the cephalometric method are: (1) Measurements are made on bony points. (2) No manipulation about the face is required once the patient is seated comfortably. (3) Concentration is placed on the patient and his state of rest rather than on the measuring device. The patient is less "jaw-conscious." (4) A permanent record and permanent reference points are available to return to months or years later.

The disadvantages of the cephalometric method are: (1) The measurements are made in strange surroundings for the patient, including ear-posts. (2) The measurements are made of "shadow pictures." (3) Special equipment is required. (4) The use of x-rays is necessary.

Read before the Academy of Denture Prosthetics, New York, N. Y., May 6, 1955.
Received for publication, Nov. 10, 1955.

If the equipment can be obtained, the other disadvantages can be overcome with the exercise of due care. The measurement of the rest position by any means is a clinical procedure and must be done by a clinician and not by a technician, for every time the operator pushes the x-ray button or uses the bite-gauge, he must make a complex clinical evaluation of the patient, deciding that the patient is truly "at rest." Therefore, the validity of the measurements depends on the clinical understanding of the operator and on that intangible "doctor-patient" relationship which is conducive to patient relaxation. To emphasize this important human factor, I refer to the "clinical" rest position rather than the "physiologic" rest position.

The Number and Timing of the Measurements.—In order to prove that the rest position is constant from birth to death, one would like to make measurements in the same individuals throughout their lives. Obviously, this is impractical. However, we may get some clues by making several observations in one examination (or sitting) and then by making several similar examinations weeks or months later.

Another approach is to look for pathologic situations, for if there is no measurable change during pathologic situations, there probably will be none during physiologic situations. The most common major sudden pathologic event which might affect the rest position is the extraction of the remaining occluding teeth. I shall refer to this as the removal of occlusal contacts. Clinical experience suggests that changes often do occur at this time, but because of the problems of measurement discussed above, good concrete data is very meager.

The Variability of the Rest Position.—On purely theoretical grounds, there may well be variability of the rest position, because the rest position is actually a postural position, and should be subject to the same physiologic and pathologic factors as is posture anywhere else in the body. Some of these factors are listed in Table I.

TABLE I

A PARTIAL LIST OF FACTORS WHICH INFLUENCE POSTURE

I. Physiologic
   A. Voluntary control
   B. Postural reflexes
   C. Fatigue and sleep
   D. Psychic factors
   E. Heat, cold, or pain
   F. Function

II. Pathologic
   A. Diseases of muscles
   B. Diseases of nerve
   C. Diseases of bone
   D. Diseases of joints
   E. Any disease causing fatigability
   F. Anesthesia and sedation
   G. Mental diseases
   H. External factors (e.g., prosthesis)
   I. Malfunction

Despite the numerous factors which may influence posture, and similarly jaw posture, it may be that because of the small size of the structures involved, the possible changes may be too small to measure, especially when crude measuring devices are used. In other words, the range of variation may be too small to measure. If such is the case, the rest position will appear constant in both physiologic and pathologic situations.

METHOD AND MATERIAL

This is a report of a cephalometric study at the Harvard School of Dental Medicine and at the Veterans Administration Hospital in Boston, with Margolis Cephalostats (except Case 13) and ordinary dental x-ray machines. Parallel studies were conducted at the two institutions to get a wider variety of physiologic and pathologic situations. The main requirement for the selection of a patient was that there be some definite occlusal contacts which were to be removed Each of the 42 patients had to satisfy this requirement and to present himself at a time to fit into a busy clinical schedule. Perhaps fortunately, this has been a clinical study, not an "ivory tower" study in the quiet recesses of a university or a hospital. Cephalometric examinations were made whenever feasible according to a general plan. Usually, two or three films were taken with the patient at rest. The vertical dimension was measured on the films from nasion to gnathion and averaged for each sitting. As a check against possible errors in magnification due to malpositioning of the patient, the constant distance from nasion to nasal spine was measured on each film, and this almost invariably proved to be constant for each patient on the films, indicating a very high accuracy of measurement and patient positioning, even though the study included approximately 300 separate sittings over a four-year period.

The general plan was to follow serially the resting vertical dimension before and after the removal of the remaining occlusal contacts. Specifically, the procedure was as follows: Patients whose diagnosis and treatment plans indicated the removal of remaining occlusal contacts were referred to the investigator for further workup prior to the extraction of the teeth. The investigator chatted amiably with the patient, took a medical and dental history on a prepared form, and, in most instances, took color photographs of the remaining teeth and of the facial profile. By the time the investigator was ready to make the baseline cephalometric examination, the patient was in most cases quite relaxed and cooperative. In fact, most patients adjusted quite readily to the cephalostat, taking it as a matter of course as just one more diagnostic procedure. If for any reason, at the time of this baseline measurement, the patient was deemed too apprehensive or unable to adjust to the cephalostat, he was not included in the study. Every effort was made to prevent the patient from becoming "jaw-conscious" or "rest position conscious." The cephalometric examinations were explained to the patient only in broad terms of helping in the later construction of the dentures, as, in fact, they usually did.

No effort was made to "condition" the patient through exercises or premedication. From the very beginning, we have wanted to study the effect of specific remedial exercises (or "conditioning"), but we felt that we must first establish some sort of a baseline from which we could measure the effectiveness of the remedial therapy.

PRESENTATION OF NEW DATA AND COMPARISON WITH DATA PRESENTED BY OTHER WORKERS

When one deals with 42 human beings, averages, mean deviations, and even standard deviations mean very little to that individual who stands at one extreme or another. All data is presented in the appendix for later analysis, but, despite the inherent dangers in so doing, let us examine some examples and some averages.

Analysis of the data shows that the rest position may vary within a single sitting between consecutive films, if the patient is allowed to talk and to return to rest. This varies from one patient to another, some varying only slightly (Nos. 13, 32, 59, 60, etc.) with others varying quite considerably (Nos. 88, 96, 104, etc.) and with others falling in between.

Likewise, the rest position may vary between different sittings, either a slight amount (Nos. 32, 59, 65, etc.) or a substantial amount (Nos. 78, 88, 96, etc.) with many graduations in between.

Analysis of the data presented by Coulombe[1] and by Thompson and Brodie[2] and Thompson[3] reveals remarkably similar findings. The data from all three studies has been analyzed in the same manner and is summarized in Table II.

The above observations were in relation to the patients only after the occlusal contacts had been removed. If one compares the pre-extraction rest position with the post-extraction rest position, one finds even greater variations, which again vary from one patient to another. Of the 42 patients studied in this manner, 11 patients showed an increase in resting vertical dimension, 9 showed a fluctuation about their individual baseline measurements, and 22 showed a decrease. Table II shows a summary of the individual variations in terms of both average findings and maximum changes. Careful analysis of Thompson's five patients shows remarkably similar trends.

In most of the patients, observations were also made after dentures were constructed. It is interesting to note that the resting vertical dimension was often different depending on whether the dentures were in or out of the mouth. In some cases, the removal of the dentures was associated with a decrease in resting vertical dimension, while in others there was an increase and in others, little or no change. For example, in No. 13, there was little or no difference, whereas in No. 56, there was an average decrease of 2.5 mm., and in No. 75 an average increase of 2.2 mm., even though all three showed an adequate free-way space with the dentures in place.

CLINICAL INTERPRETATION OF THE DATA (SEE APPENDIX)

The removal of occlusal contacts is a major, sudden, pathologic insult to the entire stomatognathic system. Not only are mechanical factors upset, allowing a range of motion (overclosure) which would otherwise be impossible, but also biologic processes are disturbed when the proprioceptive nerve endings in the periodontal membrane are destroyed. The edentulous state in the adult is a pathologic state. The data presented suggest that, like other measurements of physiologic processes, measurement of the resting vertical dimension in the edentulous patient shows a range of variation which varies from one patient to another and in the same patient from one time to another.

TABLE II

VARIATION WITHIN SINGLE SITTINGS (NO OCCLUSAL STOPS)						VARIATION BETWEEN SITTINGS (NO OCCLUSAL STOPS)									DIFFERENCE BETWEEN PRE- AND POST-EXTRACTION					
COULOMBE*			ATWOOD**			THOMPSON***			COULOMBE*			ATWOOD**			THOMPSON***			ATWOOD**		
CASE NO.	AVE. RANGE	AVE. MEAN DEV.	CASE NO.	AVE. RANGE	AVE. MEAN DEV.	CASE NO.	RANGE	MEAN DEV.	CASE NO.	RANGE	MEAN DEV.	CASE NO.	RANGE	MEAN DEV.	CASE NO.	AVE.	MAXIMUM	CASE NO.	AVE.	MAXIMUM
1	0.7	0.3	13	0.6	0.2	30	0.5	0.2	1	2.5	0.3	13	3.5	0.9	34	+1.5	+3.0	13	−1.7	−3.5
2	1.6	0.8	30	1.3	0.7	33	0.5	0.2	2	3.5	1.0	30	3.0	0.9	70	−1.2	−2.0	30	−3.6	−5.0
3	1.9	1.0	31	1.5	0.7	34	3.0	1.2	3	3.5	0.8	31	1.5	0.5	76	−2.0	−4.0	31	+0.8	+2.0
4	1.4	0.6	32	0.8	0.3	39	2.0	0.9	4	2.5	0.8	32	2.0	0.6	93	−1.3	−3.0	32	+1.3	+2.0
5	0.5	0.2	33	1.5	0.8	40	4.0	1.3	5	1.0	0.2	33	2.0	0.9	94	−3.0	−5.0	33	−2.2	−3.5
6	1.5	0.7	51	1.5	0.6	42	0.5	0.2	6	1.0	0.3	51	4.5	1.1				51	−3.4	−5.0
7	0.9	0.5	53	1.6	0.6	48	0	0	7	1.5	0.3	53	2.5	0.8				53	+2.0	+3.5
8	0.8	0.4	56	1.2	0.4	65	0	0	8	2.5	0.6	56	2.5	0.6				56	−3.0	−4.5
9	1.3	0.6	59	0.8	0.3	66	1.5	0.6	9	3.5	1.0	59	1.0	0.4				59	−1.5	−2.0
10	1.8	0.9	60	0.8	0.2	67	1.5	0.4	10	4.5	0.7	60	2.5	0.9				60	−3.3	−4.0
11	0.9	0.4	62	0.8	0.3	70	1.5	0.8	11	3.0	0.6	62	2.5	0.7				62	−0.1	+1.0 to −1.5
12	0.7	0.4	63	0.9	0.4	74	0	0	12	3.5	0.8	63	2.0	0.8				63	−1.0	0 to −2.0
14	0.8	0.4	65	0.5	0.2	76	6.0	2.7	14	3.0	1.0	65	0.5	0.2				65	+0.6	+1.0
15	1.0	0.5	66	1.5	0.4	78	7.0	3.5	15	2.5	0.8	66	4.0	1.6				66	−2.8	−4.5
16	1.0	0.5	69	0.5	0.2	80	2.0	0.7	16	1.5	0.4	69	3.5	1.2				69	−4.3	−6.0
17	0.4	0.2	72	1.5	0.5	83	0.5	0.2	17	2.5	0.6	72	1.0	0.4				72	−4.1	−4.5
18	0.8	0.4	73	1.6	0.6	85	4.0	1.3	18	3.5	0.8	73	7.0	1.5				73	−1.5	+3.0 to −4.0
19	1.2	0.6	74	1.3	0.5	87	1.0	0.4	19	2.5	0.5	74	3.0	0.9				74	−0.4	+1.0 to −2.0
20	2.9	1.4	75	0.8	0.3	90	0	0	20	3.0	1.0	75	1.5	0.6				75	+1.3	+2.0
21	0.6	0.3	76	1.0	0.4	93	3.5	1.8	21	1.5	0.3	76	2.5	1.0				76	0	+1.0 to −1.5
22	1.0	0.5	78	2.0	0.8	94	4.0	2.0	22	3.0	1.0	78	8.0	2.1				78	−3.3	−7.5
23	0.8	0.4	80	1.1	0.4	102	0.5	0.2	23	3.0	0.6	80	3.5	0.9				80	−0.5	+1.5 to −2.0
24	0.8	0.4	84	1.0	0.4	103	1.0	0.5	24	2.0	0.5	84	3.5	1.2				84	−2.4	−4.0
25	1.5	0.7	88	3.2	1.4	109	0	0	25	4.0	1.1	88	9.5	3.1				88	+2.8	+9.0
26	1.9	1.0	90	0.5	0.2	134	1.0	0.4	26	4.0	1.0	90	7.0	2.0				90	−2.9	−5.5
27	1.1	0.5	95	1.1	0.5	136	4.5	1.8	27	3.0	0.4	95	4.0	1.2				95	−1.3	−3.5
28	0.8	0.4	96	4.0	1.8	138	1.0	0.4	28	3.0	0.5	96	6.5	2.8				96	0	+3.5 to −3. 0
29	0.8	0.4	97	1.0	0.4	82	4.0	1.8	29	3.5	0.9	97	5.5	1.4				97	+4.8	+7.5
			98	1.1	0.4							98	4.0	1.3				98	+1.8	+4.0
			101	1.7	0.8							101	2.5	0.8				101	−2.1	−3.5
			103	0.3	0.1							103	1.5	0.8				103	+0.8	0 to +1.5
			104	3.5	1.4							104	3.0	1.3				104	+4.0	+5.5
			105	0.4	0.2							105	3.5	0.9				105	+1.4	+3.0
			107	1.0	0.3							107	1.0	0.6				107	−2.3	−3.0
			109	0.5	0.3							109	0.5	0.3				109	−2.3	−2.5
			110	0.7	0.3							110	5.0	1.8				110	−4.0	−6.5
			113	0.5	0.3							113	3.5	0.9				113	−0.3	+0.5 to −3.0
			114	1.0	0.5							114	2.0	0.8				114	+3.3	+4.5
			116	0.2	0.1							116	1.5	0.6				116	−4.3	−5.0
			118	0.3	0.2							118	4.0	1.3				118	−5.8	−8.0
			151	0.5	0.2							151	4.5	1.2				151	−0.3	+3.0 to −1.5
			153	1.5	0.5							153	5.0	1.1				153	−3.8	−6.5
AVE.	1.1	0.5		1.2	0.5		2.0	0.8		2.8	0.7		3.2	1.0		±1.8	±3.4		±2.2	±3.7

*Compiled from data presented by Coulombe, J. A. R.: A Serial Cephalometric Study of the Rest Position of the Mandible on Edentulous Individuals. Canad. D. A. J. 20: 536-543, Oct. 1954.
**Compiled from data presented in this article.
***Compiled from data presented by Thompson, J. R., and Brodie, A. G.: Factors in the Position of the Mandible, J.A.D.A. 29: 925-941, June, 1942; and by Thompson, J. R.: The Rest Position of the Mandible and Its Significance to Dental Science; J.A.D.A. 33: 151-180, Feb., 1946.

Because of the variability and complexity of human beings, it seems imperative to emphasize that no attempt should be made to translate any of this data into any magic numbers or rules which would then be applied to all patients. This type of oversimplification often breeds confusion, as in the case of the free-way space. It may be true that the interocclusal gap is very often 2 to 3 mm., but by no means is this invariable.

To observe variability is one thing; to explain it, another. Why did some patients vary more than others? Why did the resting vertical dimension increase following the removal of occlusal contacts in some patients, while decreasing in others? The problem is much too complex to make a simple categorical reply. In order to try to unravel some of the important threads, the 42 patients in this study were analyzed in regard to many factors which will be discussed in Part III in this article.

The fact that there was an average closure following the removal of occlusal contacts in 22 out of 42 patients of 3 mm. does *not* answer the question as to whether we can safely restore this lost vertical dimension with dentures. This important clinical question will be taken up in Part II.

SUMMARY

1. For each physiologic process, there is both a physiologic and a pathologic range of variability.

2. Man's ability to detect this variability depends on: the accuracy and validity of his measurements, the number and timing of his measurements, and the variability of the physiologic process.

3. The variability of the resting vertical dimension was studied clinically in 42 patients. By timing the cephalometric measurements before and after a major pathologic event—the removal of occlusal contacts—variability should appear, if it does occur and if it is measurable.

4. Variability was measurable and of clinical significance in edentulous patients between different readings within a single sitting, between average readings of different sittings, and between readings with and without dentures. Even greater variations existed between pre- and post-extraction readings. In each regard, variability was different for different patients and for the same patient at different times.

5. Of the 42 patients, 11 showed an increase in resting vertical dimension following the removal of occlusal contacts, 9 fluctuated about their individual baselines, and 22 showed a decrease.

6. The fact of closure in 22 out of 42 patients does not answer the question of safe restoration of lost vertical dimension with dentures. This question will be discussed further in Part II.

REFERENCES

1. Coulombe, I. A. R.: A Serial Cephalometric Study of the Rest Position of the Mandible on Edentulous Individuals, J. Canad. D. A. **20**:536-543, 1954.
2. Thompson, J. R., and Brodie, A. G.: Factors in the Position of the Mandible, J.A.D.A. **29**:925-941, 1942.
3. Thompson, J. R.: The Rest Position of the Mandible and Its Significance to Dental Science, J.A.D.A. **33**:151-180, 1946.

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***Compiled from data presented by Thompson, J. R., and Brodie, A. G.: Factors in the Position of the Mandible, J.A.D.A. 33: 151-180, Feb., 1946.

APPENDIX*

CASE NO.	TIME RELATIVE TO EXTRACTION OF OCCLUSAL STOPS	TIME RELATIVE TO RESTORATION WITH:	PRE-EXTRACTION VERTICAL DIMENSION								POST-EXTRACTION VERTICAL DIMENSION														DIFFERENCE BETWEEN REST WITH AND REST WITHOUT DENTURES	DIFFERENCE BETWEEN PRE-EXTRACTION REST WITH TEETH AND POST-EXTRACTION REST WITHOUT DENTURES
			REST (WITH NATURAL TEETH)						OCCLUSAL	FREE-WAY SPACE	REST (WITH DENTURES)						OCCLUSAL	FREE-WAY SPACE	REST (WITHOUT DENTURES)							
			I	II	III	AVE.	RANGE	MEAN DEV.			I	II	III	AVE.	RANGE	MEAN DEV.			I	II	III	AVE.	RANGE	MEAN DEV.		
13	PRE		119.0	119.0		119.0	0	0	119.0	0																
	POST 1 mo.	PRE FU/FL																	119.5	119.0	118.0	119.0	1.5	0.5		0
	1½ mo.																		118.0	118.5	118.5	118.5	0.5	0.2		−0.5
	2 mo.																		117.5	117.0	117.0	117.0	0.5	0.2		−2.0
	3 mo.																		118.5	118.5	117.5	118.0	1.0	0.4		−1.0
	3½ mo.																		117.5	118.0	118.0	118.0	0.5	0.2		−1.0
	4 mo.	Set-up FU/FL															116.5									
	4 mo.	Insertion															118.0									
	7 mo.	POST 3 mo.									117.0	117.0	117.0	117.0	0	0	116.5	0.5	118.0	117.5	117.0	117.5	1.0	0.3	+0.5	−1.5
	35 mo.	31 mo.									116.0	116.5		116.5	0.5	0.3	114.0	2.5	117.0	116.5		116.5	0.5	0.3	0	−2.5
	37 mo.	33 mo.									115.5	116.0		116.0	0.5	0.3	114.0	2.0	115.5	115.5		115.5	0	0	−0.5	−3.5
	39 mo.	POST-REBASE									117.5	117.5		117.5	0	0	115.5	2.0	117.0	117.5		117.5	0.5	0.3	0	−1.5
	50 mo.	46 mo.									116.0	116.5		116.0	0.5	0.3	114.5	1.5	116.0	116.0		116.0	0	0	0	−3.0
									AVE.: WITHIN SINGLE SITTINGS					116.6	0.3	0.2		1.7				117.3	0.6	0.2	0	−1.7
									RANGE: BETWEEN DIFFERENT SITTINGS					1.5								3.5				
									MEAN DEV.: BETWEEN SITTINGS					0.5								0.9				
30	PRE		121.5	121.5		121.5	0	0	120.0	1.5																
	POST 2 mo.	PRE FU/FL																	118.0	119.0		118.5	1.0	0.5		−3.0
	2 mo.																		119.0	120.5		119.5	1.5	0.8		−2.0
	12 mo.	POST 8 mo.									118.5	118.0		118.5	0.5	0.3	117.5	1.0	117.0	119.0		118.0	2.0	1.0	−0.5	−3.5
	18 mo.	14 mo.									118.0	118.5		118.5	0.5	0.3	117.0	1.5	116.0	118.0		117.0	2.0	1.0	−1.5	−4.5
																			116 5	116.5		116.5	0	0	−2.0	−5.0
									AVE.: WITHIN SINGLE SITTINGS					118.5	0.5	0.3		1.3				117.9	1.3	0.7	−1.3	−3.6
									RANGE: BETWEEN DIFFERENT SITTINGS					0								3.0				
									MEAN DEV.: BETWEEN SITTINGS					0								0.9				
31	PRE		121.0	121.5		121.5	0.5	0.3	119.5	2.0																
	POST 2 mo.	PRE FU/FL																	121.5	122.5	122.5	122.0	1.0	0.4		+0.5
	2 mo.	Wax Rims															122.0		121.5	123.0		122.0	1.5	0.8		+0.5
	4 mo.	POST ½ mo.									123.0	123.0		123.0	0	0	122.0	1.0								
	12 mo.	8 mo.									123.5	124.5		124.0	1.0	0.5	122.0	2.0	122.5	122.0		122.0	0.5	0.2	−2.0	+0.5
	18 mo.	14 mo.									123.0	124.0		123.5	1.0	0.5	122.0	1.5	122.0	124.5		123.5	2.5	1.3	0	+2.0
	28 mo.	24 mo.									123.0	125.0		124.0	2.0	1.0	122.0	2.0	121.5	123.0		122.0	1.5	0.8	−2.0	+0.5
									AVE.: WITHIN SINGLE SITTINGS					123.6	1.0	0.5		1.8				122.3	1.5	0.7	−1.3	+0.8
									RANGE: BETWEEN DIFFERENT SITTINGS					1.0								1.5				
									MEAN DEV.: BETWEEN SITTINGS					0.4								0.5				
32	PRE		138.0	137.0		137.5	1.0	0.5	137.0	0.5																
	PRE		138.0	137.5		137.5	0.5	0.3	137.0	0.5																
	POST 1 mo.	PRE FU/PL																	137.5	137.5	137.5	137.5	0	0		0
	8 mo.	POST 6 mo.									140.0	140.0		140.0	0	0	138.0	2.0	138.5	139.5		139.0	1.0	0.5	−1.0	+1.5
	14 mo.	12 mo.									139.0	140.0		139.5	1.0	0.5	138.0	1.5	139.5	139.5		139.5	0	0	0	+2.0
	14 mo.	12 mo.									140.0	139.5		139.5	0.5	0.2	138.0	1.5	138.0	139.0		138.5	1.0	0.5	−1.0	+1.0
	19 mo.	17 mo.									140.0	139.5		139.5	0.5	0.2	138.0	1.5	139.5	139.0		139.0	0.5	0.2	−0.5	+1.5
	24 mo.	22 mo.									138.5			138.5			138.0	0.5	140.0	138.5	140.0	139.5	1.5	0.7	+1.0	+2.0
									AVE.: WITHIN SINGLE SITTINGS					139.4	0.5	0.2		1.4				138.8	0.8	0.3		+1.3
									RANGE: BETWEEN DIFFERENT SITTINGS					1.5								2.0				
									MEAN DEV.: BETWEEN SITTINGS					0.4								0.6				

*Publication of this appendix was made possible by a grant from the William E. Milton Fund of Howard University.

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33	PRE		150.0	150.0		150.0	0	0	149.5	0.5									147.5	146.0		146.5	1.5	0.8		−3.5
	POST ½ mo.	PRE FU/FL																	147.5	149.5		148.5	2.0	1.0	+0.5	−1.5
	5 mo.	Insertion									148.5	147.5														
	28 mo.	POST 23 mo.									148.0	147.0	148.0	1.0	0.5	147.0	1.0		148.0	149.0		148.5	1.0	0.5	+1.0	−1.5
													147.5	1.0	0.5	144.5	3.0									
									AVE.: WITHIN SINGLE SITTINGS				147.7	1.0	0.5		2.0					147.8	1.5	0.8	+0.8	−2.2
									RANGE: BETWEEN DIFFERENT SITTINGS				0.5									2.0				
									MEAN DEV.: BETWEEN SITTINGS				0.2									0.9				
51	PRE		143.0	143.0		143.0	0	0	142.5	0.5									143.0	142.5	141.5	142.5	1.5	0.5		−0.5
	POST 1 wk.	PRE FU																	137.0	138.0	138.5	138.0	1.5	0.5		−5.0
	2 wk.																		138.5	139.0	139.0	139.0	0.5	0.2		−4.0
	3 wk.																		139.0	140.5	140.5	140.0	1.5	0.5		−3.0
	1 mo.																		139.0	141.0		140.0	2.0	1.0	−4.5	−3.0
	2 mo.	POST FU ½ mo.									144.0	145.0	144.5	1.0	0.5	142.0	2.5		139.0	138.5		139.0	0.5	0.2	−4.0	−4.0
	6 mo.	4½ mo.									142.0	143.5	143.0	1.5	0.8	142.0	1.0		137.5	139.0		138.5	1.5	0.8		−4.5
									AVE.: WITHIN SINGLE SITTINGS				143.8	1.2	0.6		1.8					139.6	1.5	0.6	−4.3	−3.4
									RANGE: BETWEEN DIFFERENT SITTINGS				1.5									4.5				
									MEAN DEV.: BETWEEN SITTINGS				0.8									1.1				
53	PRE		136.0	135.0		135.5	1.0	0.5	132.5	3.0									137.5	138.0	138.5	138.0	1.0	0.3		+2.5
	POST 1 wk.	PRE FU/PL																	136.5	137.5	137.0	137.0	1.0	0.3		+1.5
	1 mo.																		135.0	137.5	137.5	136.5	2.5	1.1		+1.0
	5 mo.																		138.0	136.0		137.0	2.0	1.0	+0.5	+1.5
	9 mo.	POST 1½ mo.									136.0	136.5	136.5	0.5	0.2	136.0	0.5		139.0	138.5		139.0	0.5	0.2	+3.5	+3.5
	15½ mo.	8 mo.									135.5	135.5	135.5	0	0	135.0	0.5									
									AVE.: WITHIN SINGLE SITTINGS				136.0	0.2	0.1		0.5					137.5	1.6	0.6	+2.0	+2.0
									RANGE: BETWEEN DIFFERENT SITTINGS				1.0									2.5				
									MEAN DEV.: BETWEEN SITTINGS				0.5									0.8				
56	PRE		140.0	140.0		140.0	0	0	137.0	3.0									138.0	136.0		137.0	2.0	1.0		−3.0
	POST 3 da.	PRE FU/FL																	136.0	136.5	136.5	136.5	0.5	0.2		−3.5
	1 wk.																		138.5	137.5		138.0	1.0	0.5		−2.0
	10 da.																		137.0	137.5	137.0	137.0	0.5	0.2		−3.0
	3 wk.																		138.0	137.5	139.0					
	7 wk.																		138.5	138.0		138.0	1.5	0.4		−2.0
																137.5										
	10 wk.	Set-up														137.5			136.5	137.5	137.5	137.0	1.0	0.4		−3.0
	3 mo.	Insertion									140.5	140.0	140.5	0.5	0.2	138.5	2.0		135.5	137.5		136.5	2.0	1.0	−4.0	−3.5
	3¼ mo.	POST Grind-in									141.5	139.5	140.5	2.0	1.0	137.5	3.0		136.0	137.0		136.5	1.0	0.5	−4.0	−3.5
	6 mo.	POST 3 mo.									139.5	137.5	138.5	2.0	1.0	135.5	3.0		135.5	135.5		135.5	0	0	−3.0	−4.5
	8 mo.	5 mo.									138.5	138.5	138.5	0	0	134.5	4.0		135.5	136.0	137.0					
																			136.5			136.5	1.5	0.5	−2.0	−3.5
	15 mo.	12 mo.									138.0	137.0	137.5	1.0	0.5	133.5	4.0		137.5	138.0		138.0	0.5	0.2	+0.5	−2.0
									AVE.: WITHIN SINGLE SITTINGS				139.1	1.1	0.5		2.8					137.0	1.2	0.4	−2.5	−3.0
									RANGE: BETWEEN DIFFERENT SITTINGS				4.0									2.5				
									MEAN DEV.: BETWEEN SITTINGS				1.1									0.6				
59	PRE		140.5	140.0		140.5	0.5	0.3	140.0	0.5									139.5	139.0	139.5	139.5	0.5	0.2		−1.0
	POST 1 wk.	PRE FU/FL																	139.0	139.5	140.0	139.5	1.0	0.3		−1.0
	2 wk.																		139.0	138.5	139.0	139.0	0.5	0.2		−1.5
	4 wk.																		138.5	139.0		138.5	0.5	0.2	−4.5	−2.0
	4½ mo.	POST 1½ mo.									142.5	143.5	143.0	1.0	0.5	142.0	1.0		139.0	138.0		138.5	1.0	0.5	−4.0	−2.0
	16 mo.	13 mo.									142.5	142.0	142.5	0.5	0.2	141.0	1.5									
									AVE.: WITHIN SINGLE SITTINGS				142.8	0.8	0.4		1.3					139.0	0.8	0.3	−4.3	−1.5
									RANGE: BETWEEN DIFFERENT SITTINGS				0.5									1.0				
									MEAN DEV.: BETWEEN SITTINGS				0.3									0.4				

CASE NO.	TIME RELATIVE TO EXTRACTION OF OCCLUSAL STOPS	TIME RELATIVE TO RESTORATION WITH:	PRE-EXTRACTION VERTICAL DIMENSION								POST-EXTRACTION VERTICAL DIMENSION														DIFFERENCE BETWEEN REST WITH AND REST WITHOUT DENTURES	DIFFERENCE BETWEEN PRE-EXTRACTION REST WITH TEETH AND POST-EXTRACTION REST WITHOUT DENTURES
			REST (WITH NATURAL TEETH)						OCCLUSAL	FREE-WAY SPACE	REST (WITH DENTURES)						OCCLUSAL	FREE-WAY SPACE	REST (WITHOUT DENTURES)							
			I	II	III	AVE.	RANGE	MEAN DEV.			I	II	III	AVE.	RANGE	MEAN DEV.			I	II	III	AVE.	RANGE	MEAN DEV.		
60	PRE		129.0	129.5		129.0	0.5	0.3	126.5	2.5																
	POST 1 wk.	PRE FU/FL																	127.5	127.5	127.5	127.5	0	0		−1.5
	1 mo.																		125.0	125.5	125.5					
																			123.5	124.5		125.0	2.0	0.6		−4.0
	4 mo.																		125.0	125.5	125.0	125.0	0.5	0.2		−4.0
	6½ mo.																		127.5	127.5	128.0					
																			127.5	125.0	126.5					
																			126.5			127.0	3.0	0.8		−2.0
	7 mo.																		126.0	125.0	125.0					
																			124.0	125.5		125.0	2.0	0.5		−4.0
	8 mo.	POST 3 wk.									127.5	126.5		127.0	1.0	0.5	126.0	1.0	125.0	125.0		125.0	0	0	−2.0	−4.0
																			125.0	125.0		125.0	0	0	−2.0	−4.0
									AVE.: WITHIN SINGLE SITTINGS													125.7	0.8	0.2	−2.0	−3.3
									RANGE: BETWEEN DIFFERENT SITTINGS													2.5				
									MEAN DEV.: BETWEEN SITTINGS													0.9				
62	PRE		134.5	134.5		134.5	0	0	133.0	1.5																
	POST 2 wk.	PRE FU/FL																	135.0	135.5		135.5	0.5	0.2		+1.0
	3 wk.																		133.5	136.0		134.5	1.5	0.8		0
	4 wk.																		133.0	132.5	133.5	133.0	1.0	0.3		−1.5
	2 mo.																		135.5	135.0	135.5	135.5	0.5	0.2		+1.0
	2¼ mo.																		132.5	132.5	134.0	133.0	1.5	0.7		−1.5
	4½ mo.																		135.5	135.0	135.5	135.5	0.5	0.2		+1.0
	8 mo.	POST 1 mo.									135.5	137.0		136.5	1.5	0.8	135.0	1.5	134.5	134.5		134.5	0	0	−2.0	0
																			134.0	134.5	134.0	134.0	0.5	0.2		−0.5
	17 mo.	10 mo.									136.0	136.5		136.0	0.5	0.2	135.0	1.0	135.0	134.0		134.5	1.0	0.5	−1.5	0
									AVE.: WITHIN SINGLE SITTINGS					136.3	1.0	0.5		1.3				134.4	0.8	0.3	−1.8	−0.1
									RANGE: BETWEEN DIFFERENT SITTINGS					0.5								2.5				
									MEAN DEV.: BETWEEN SITTINGS					0.3								0.7				
63	PRE		129.5	130.0		130.0	0.5	0.2	127.5	2.5																
	POST 1 wk.	PRE FU/PL																	128.5	128.0	128.0	128.0	0.5	0.2		−2.0
	2 wk.																		130.0	131.0	130.0	130.0	1.0	0.3		0
	3 wk.																		130.0	129.0		129.5	1.0	0.5		−0.5
	4½ mo.	POST 1 mo.									131.5	131.0		131.5	0.5	0.2	131.0	0.5	129.0	128.0		128.5	1 0	0.5	−3.0	−1.5
									AVE.: WITHIN SINGLE SITTINGS													129.0	0.9	0.4	−3.0	−1.0
									RANGE: BETWEEN DIFFERENT SITTINGS													2.0				
									MEAN DEV.: BETWEEN SITTINGS													0.8				
65	PRE		137.0	136.5		137.0	0.5	0.3	133.0	4.0																
	POST 2 wk.	PRE FU																	138.0	137.0	137.5	137.5	1.0	0.3		+0.5
	3 wk.																		137.5	137.5	137.0	137.5	0.5	0.2		+0.5
	4 mo.	POST 3 mo.									139.0	140.5		139.5	1.5	0.8	135.5	4.0	138.0	138.5		138.0	0.5	0.3	−1.5	+1.0
	15 mo.	14 mo.									135.5	137.0		136.5	1.5	0.8	134.5	2.0	137.5	137.5	137.5	137.5	0	0	+1.0	+0.5
									AVE.: WITHIN SINGLE SITTINGS					138.0	1.5	0.8		3.0				137.6	0.5	0.2	−0.2	+0.6
									RANGE: BETWEEN DIFFERENT SITTINGS					3.0								0.5				
									MEAN DEV.: BETWEEN SITTINGS					1.5								0.2				

66	PRE		134.5	135.0		135.0	0.5	0.3	132.5	2.5															
	POST 1 wk.	PRE FU/FL																	134.0	134.0		134.0	0	0		−1.0
	2 mo.																		134.5		134.0					
																			134.5	135.0		134.5	1.0	0.2		−0.5
	2½ mo.																		131.0	132.5	131.5	131.5	1.5	0.7		−3.5
	3½ mo.																		130.0	130.5	130.5	130.5	0.5	0.2		−4.5
	5½ mo.																		130.0	132.0	130.5					
																			131.5	130.5	129.0					
																			129.0			130.5	3.0	0.9		−4.5
									AVE.: WITHIN SINGLE SITTINGS													132.2	1.5	0.4		−2.8
									RANGE: BETWEEN DIFFERENT SITTINGS													4.0				
									MEAN DEV.: BETWEEN SITTINGS													1.6				
69	PRE		145.5	145.5		145.5	0	0	144.5	1.0																
	POST 1 wk.																		143.0	143.0		143.0	0	0		−2.5
	2 wk.																		141.5	141.0	140.5	141.0	1.0	0.3		−4.5
	3 mo.																		139.5	139.0	139.5	139.5	0.5	0.2		−6.0
									AVE.: WITHIN SINGLE SITTINGS													141.2	0.5	0.2		−4.3
									RANGE: BETWEEN DIFFERENT SITTINGS													3.5				
									MEAN DEV.: BETWEEN SITTINGS													1.2				
72	PRE		144.5						145.0																	
	POST 2 wk.																		139.0	140.0	140.5	140.0	1.5	0.5		−4.5
	2 mo.																		141.0	142.0	140.5	141.0	1.5	0.5		−3.5
	2½ mo.																		139.5	140.0	141.0	140.0	1.5	0.5		−4.5
	3 mo.																		139.5	140.5	141.0	140.5	1.5	0.5		−4.0
									AVE.: WITHIN SINGLE SITTINGS													140.4	1.5	0.5		−4.1
									RANGE: BETWEEN DIFFERENT SITTINGS													1.0				
									MEAN DEV.: BETWEEN SITTINGS													0.4				
74	PRE		140.0	140.0		140.0	0	0	136.5	3.5																
	POST 1 wk.	PRE FU/FL																	140.0	142.0	142.0	141.0	2.0	0.9		+1.0
	3½ mo.																		138.0	138.5	138.0	138.0	0.5	0.2		−2.0
	7 mo.	POST 3 mo.									139.5	139.5	139.5	0	0	136.0	3.5		139.5	138.5		139.0	1.0	0.5	−0.5	−1.0
																			139.0	140.5		140.0	1.5	0.8	+0.5	0
	13 mo.	9 mo.									140.0	139.0	139.5	1.0	0.5	136.0	3.5		140.0	139.5	140.5	140.0	1.0	0.3	+0.5	0
									AVE.: WITHIN SINGLE SITTINGS				139.5	0.5	0.3		3.5					139.6	1.3	0.5	+0.2	−0.4
									RANGE: BETWEEN DIFFERENT SITTINGS				0									3.0				
									MEAN DEV.: BETWEEN SITTINGS				0									0.9				
73	PRE		126.0	126.0		126.0	0	0	120.5	5.5																
	POST 4 da.	PRE FU/FL																	127.5	130.0	129.5	129.0	2.5	1.0		+3.0
	1 wk.																		126.5	122.0	124.5	124.5	4.5	1.5		−1.5
	2 wk.																		122.5	126.5	124.5	124.5	4.0	1.3		−1.5
	1 mo.																		124.5	122.0	122.0	123.0	2.5	1.1		−3.0
	1½ mo.																		124.0	123.5	123.5	123.5	0.5	0.2		−2.5
	2 mo.																		123.0	122.5	120.5	122.0	2.5	1.0		−4.0
	2¼ mo.																		122.5	123.5	122.5	123.0	1.0	0.4		−3.0
	2¾ mo.	Set-up																	125.0	124.0		124.5	1.0	0.5		−1.5
	3¼ mo.	POST Grind-in														125.5										
	3¾ mo.	3 wk.									124.0	126.5	125.5	1.5	0.8	123.5	2.0		123.0	123.0		123 0	0	0	−2.5	−3.0
	4 mo.	REBASE																	123.5	126.0	125.0	125.0	2.5	0.9		−1.0
	5 mo.	2 mo.									125.0	128.0	126.5	3.0	1.5	125.0	1.5		123.5	124.0		123.5	0.5	0.2	−3.0	−2.5
	7 mo.	4 mo.									126.0	126.5	126.5	0.5	0.2	125.0	1.5		123.0	122.5		123.0	0.5	0.2	−3.0	−3.5
											131.0	128.0	129.5	3.0	1.5	125.0	4.5		126.5	127.0		126.5	0.5	0.2	−3.0	−3.0
																			127.5	128.5		128.0	1.0	0.5	−1.5	+0.5
									AVE.: WITHIN SINGLE SITTINGS				127.0	2.0	1.0		2.4					124.5	1.6	0.6	−2.7	+2.0
									RANGE: BETWEEN DIFFERENT SITTINGS				4.0									7.0				−1.5
									MEAN DEV.: BETWEEN SITTINGS				1.2									1.5				

CASE NO.	TIME RELATIVE TO EXTRACTION OF OCCLUSAL STOPS	TIME RELATIVE TO RESTORATION WITH:	PRE-EXTRACTION VERTICAL DIMENSION								POST-EXTRACTION VERTICAL DIMENSION														DIFFERENCE BETWEEN REST WITH AND REST WITHOUT DENTURES	DIFFERENCE BETWEEN PRE-EXTRACTION REST WITH TEETH AND POST-EXTRACTION REST WITHOUT DENTURES
			REST (WITH NATURAL TEETH)						OCCLUSAL	FREE-WAY SPACE	REST (WITH DENTURES)						OCCLUSAL	FREE-WAY SPACE	REST (WITHOUT DENTURES)							
			I	II	III	AVE.	RANGE	MEAN DEV.			I	II	III	AVE.	RANGE	MEAN DEV.			I	II	III	AVE.	RANGE	MEAN DEV.		
75	PRE		153.0	153.0		153.0	0	0	150.5	2.5																
	POST 1 wk.	PRE FU/PL																	154.0	154.5	154.0	154.0	0.5	0.2		+1.0
	3½ mo.																		155.0	155.0	155.0					
	7 mo.	POST 1 wk.									152.0	151.5		151.5	0.5	0.2	149.5	2.0	156.0	155.0		155.0	1.0	0.3		+2.0
	13½ mo.	7 mo.									153.0	152.5		153.0	0.5	0.2	149.5	3.5	154.5	155.5		155.0	1.0	0.5	+3.5	+2.0
																			154.0	154.0		154.0	0	0	+2.5	+1.0
																			153.0	154.0		153.5	1.0	0.5	+0.5	+0.5
									AVE.: WITHIN SINGLE SITTINGS					152.8	0.5	0.2		2.8				154.3	0.8	0.3	+2.2	+1.3
									RANGE: BETWEEN DIFFERENT SITTINGS					1.5								1.5				
									MEAN DEV.: BETWEEN SITTINGS					0.8								0.6				
76	PRE		117.0	116.0		116.5	1.0	0.5	114.5	2.0																
	POST 2 wk.	PRE FU/FL																	115.5	115.0	115.0	115.0	0.5	0.2		−1.5
	6 wk.																		116.5	115.5	116.5	116.0	1.0	0.4		−0.5
	2 mo.																		116.5	118.5	117.5	117.5	2.0	0.7		+1.0
	2½ mo.																		117.0	118.0	118.0	117.5	1.0	0.4		+1.0
	3 mo.																		115.0	115.0		115.0	0	0		−1.5
	3½ mo.	Insertion															119.5		117.0	118.5	115.5					
																			116.0			117.0	3.0	1.0		+0.5
	5½ mo.	POST Grind-in									119.5	119.5		119.5	0	0	118.0	1.5	117.5	117.5		117.5	0	0	−2.0	+1.0
																			117.0	117.5		117.5	0.5	0.2	−2.0	+1.0
									AVE : WITHIN SINGLE SITTINGS													116.5	1.0	0.4	−2.0	0
									RANGE: BETWEEN DIFFERENT SITTINGS													2.5				
									MEAN DEV : BETWEEN SITTINGS													1.0				
78	PRE		142.5	142.5		142.5	0	0	130.5	12.0																
	POST 1 wk.	PRE FU/FL																	142.5	143.5	143.5	143.0	1.0	0.4		+0.5
	2 wk.																		142.5	141.5		142.0	1.0	0.5		−0.5
	3 wk.																		136.0	141.0	140.0	139.0	5.0	2.0		−3.5
	6 wk.																		138.5	139.5	140.5	139.5	2.0	0.7		−3.0
	2 mo.																		137.0	138.5		138.0	1.5	0.8		−4.5
	2½ mo.	Set-up															132.5		133.5	136.5		135.0	3.0	1.5		−7.5
	3 mo.	Insertion															133.0		139.5			139.5				−3.0
	3½ mo.	POST 2 wk.									139.0	137.0		138.0	2.0	1.0	132.0	6.0	136.5			136.5			−1.5	−4.5
	4½ mo.	1½ mo.									139.0	132.5		135.5	6.5	3.2	132.0	3.5	136.0	138.0		137.0	2.0	1.0	+1.5	−5.5
	7 mo.	3 mo.									141.5	141.5		141.5	0	0	130.0	11.5	142.5	143.0		142.5	0.5	0.2	+1.0	0
	14½ mo.	11½ mo.									139.0	137.0		138.0	2.0	1.0	128.0	10.0	135.5	136.5	136.0					
																			135.5			136.0	1.0	0.4	−2.0	−6.5
									AVE.: WITHIN SINGLE SITTINGS					138.2	2.6	1.3		7.8				139.2	2.0	0.8	−0.3	−3.3
									RANGE: BETWEEN DIFFERENT SITTINGS					6.0								8.0				
									MEAN DEV.: BETWEEN SITTINGS					1.6								2.1				

80	PRE		133.0	133.0	132.5	133.0	0.5	0.2	131.5																			
									131.5	1.5																		
	POST 1 wk.	PRE FU/PL																		134.5	134.5	134.0	134.5	0.5	0.2		+1.5
	3 wk.																			131.5	131.5	133.5	132.0	2.0	0.9		−1.0
	2 mo.																			131.0	132.0	133.0	132.0	2.0	0.7		−1.0
	3¼ mo.																			132.5	132.5	133.5	133.0	1.0	0.4		0
	4 mo.	Insertion									132.0	132.5		132.5	0.5	0.2	131.5	1.0	132.5	133.0			133.0	0.5	0.2	+0.5	0
	6½ mo.	POST 2½ mo.									131.5	131.5		131.5	0	0	131.5	0	131.5	131.0	130.0	131.0	131.5	0.5	0.5	−0.5	−2.0
	13 mo.	9 mo.									132.0	132.0		132.0	0	0	131.5	0.5	132.0	132.0		132.0	132.0	0	0	0	−1.0
									AVE.: WITHIN SINGLE SITTINGS					132.0	0.2	0.1		0.5				132.5	1.1	0.4	0	−0.5
									RANGE: BETWEEN DIFFERENT SITTINGS					1.0								3.5				
									MEAN DEV.: BETWEEN SITTINGS					0.3								0.9				
84	PRE		139.5	138.5	138.5	139.0	1.0	0.3	136.5																			
	POST 2 wk.	PRE FU/FL							136.5	2.5										136.5	137.0	137.5	137.0	1.0	0.3		−2.0
	1 mo.																			139.0	138.5	137.5	138.5	1.5	0.5		−0.5
	2 mo.																			137.5	139.0	139.5	138.5	2.0	0.8		−0.5
	2½ mo.																			138.0	137.0		137.5	1.0	0.5		−1.5
	3 mo.	Insertion									141.0	141.0		141.0	0	0	140.5	0.5	135.5	135.0		135.5	0.5	0.2	−5.5	−3.5
	4 mo.	POST Grind-in									141.0	139.5		140.0	1.5	0.8	139.0	1.0	136.5	138.0		137.5	1.5	0.8	−2.5	−1.5
	5½ mo.	POST 2½ mo.									138.0	138.0		138.0	0	0	138.0	0	135.5	134.5		135.0	1.0	0.5	−3.0	−4.0
	5½ mo.	POST Grind-in															137.0		135.0	135.0		135.0	0	0	−3.0	−4.0
																			135.5	136.0	136.0	136.0	0.5	0.2	−2.0	−3.0
	12 mo.	9 mo.									137.0	137.0		137.0	0	0	136.5	0.5	135.0	135.5		135.5	0.5	0.2	−1.5	−3.5
									AVE.: WITHIN SINGLE SITTINGS					139.0	0.4	0.2		0.5				136.6	1.0	0.4	−3.0	−2.4
									RANGE: BETWEEN DIFFERENT SITTINGS					4.0								3.5				
									MEAN DEV.: BETWEEN SITTINGS					1.5								1.2				
88	PRE		161.5	157.5		159.5	4.0	2.0	154.0	5.5																		
	POST 1 wk.	PRE FU/PL																		158.0	159.5		159.0	1.5	0.8		−0.5
	6 wk.																			167.5	170.5	167.5	168.5	3.0	1.3		+9.0
	4 mo.	Insertion									161.5	162.5		162.0	1.0	0.5	157.5	4.5	161.0	163.5		162.0	2.5	1.3	0	+2.5
	4½ mo.	POST 2 wk.									161.0	161.0	162.0															
											162.0			161.5	1.0	0.5	157.5	4.0	157.0	161.5		159.5	4.5	2.3	−2.0	0
									AVE.: WITHIN SINGLE SITTINGS					161.8	1.0	0.5		4.3				162.3	3.2	1.4	−1.0	+2.8
									RANGE: BETWEEN DIFFERENT SITTINGS					0.5								9.5				
									MEAN DEV.: BETWEEN SITTINGS					0.2								3.1				
90	PRE		126.5	126.0		126.5	0.5	0.3	124.5	2.0																		
	POST 1 wk.	PRE FU/PL																		127.0	128.0	128.5	128.0	1.5	0.5		+1.5
	1 mo.																			124.5	125.5	125.5	125.0	1.0	0.4		−1.5
	2 mo.																			125.0	125.5	125.0	125.0	0.5	0.2		−1.5
	4½ mo.	POST 1 mo.									132.0	132.0		132.0	0	0	131.5	0.5	121.0	121.0		121.0	0	0	−11.0	−5.5
	5½ mo.	2 mo.									130.5	131.5		131.0	1.0	0.5	130.5	0.5	121.0	121.0		121.0	0	0	−10.0	−5.5
																			122.5	123.0		123.0	0.5	0.2	− 8.0	−3.5
	1 yr.	8½ mo.									130.0	130.0		130.0	0	0	130.0	0	122.0	122.0		122.0	0	0	− 8.0	−4.5
									AVE.: WITHIN SINGLE SITTINGS					131.0	0.3	0.2		0.3				123.6	0.5	0.2	− 9.2	−2.9
									RANGE: BETWEEN DIFFERENT SITTINGS					2.0								7.0				
									MEAN DEV.: BETWEEN SITTINGS					0.6								2.0				

CASE NO.	TIME RELATIVE TO EXTRACTION OF OCCLUSAL STOPS	TIME RELATIVE TO RESTORATION WITH:	PRE-EXTRACTION VERTICAL DIMENSION								POST-EXTRACTION VERTICAL DIMENSION														DIFFERENCE BETWEEN REST WITH AND REST WITHOUT DENTURES	DIFFERENCE BETWEEN PRE-EXTRACTION REST WITH TEETH AND POST-EXTRACTION REST WITHOUT DENTURES
			REST (WITH NATURAL TEETH)						OCCLUSAL	FREE-WAY SPACE	REST (WITH DENTURES)						OCCLUSAL	FREE-WAY SPACE	REST (WITHOUT DENTURES)							
			I	II	III	AVE.	RANGE	MEAN DEV.			I	II	III	AVE.	RANGE	MEAN DEV.			I	II	III	AVE.	RANGE	MEAN DEV.		
95	PRE		125.0	124.5		125.0	0.5	0.3	123.5	1.5																
	POST 1 wk.	PRE FU/PL																	125.0	126.0	126.0	125.5	1.0	0.4		+0.5
	6 wk.																		124.0	123.0	126.0	124.5	3.0	1.1		−0.5
	3 mo.																		123.5	124.0	124.0	124.0	0.5	0.2		−1.0
	4 mo.																		121.5	122.5		122.0	1.0	0.5		−3.0
	4¼ mo.																		122.0	121.0		121.5	1.0	0.5		−3.5
	5 mo.	POST 2 wk.									126.0	126.0		126.0	0	0	124.5	1.5	123.5	123.5		123.5	0	0	−2.5	−1.5
	13 mo.	8½ mo.									126.5	125.0		126.0	1.5	0.8	124.5	1.5	125.5	124.5		125.0	1.0	0.5	−1.0	0
									AVE.: WITHIN SINGLE SITTINGS					126.0	0.8	0.4		1.5				123.7	1.1	0.5	−1.8	−1.3
									RANGE: BETWEEN DIFFERENT SITTINGS					0								4.0				
									MEAN DEV.: BETWEEN SITTINGS					0								1.2				
96	PRE		144.5	147.5		146.0	3.0	1.5	138.0	8.0																
	POST 1½ mo.	PRE FU/FL																	145.5	144.5	139.0	143.0	6.5	2.7		−3.0
	2½ mo.	Set-up															139.5		150.0	146.0		148.0	4.0	2.0		+2.0
	3¼ mo.	Insertion																								
		POST Grind-in									146.5	147.0		146.5	0.5	0.2	139.0	7.5	147.5	151.5		149.5	4.0	2.0	+3.0	+3.5
	4½ mo.	POST 1¼ mo.									141.0	142.0		141.5	1.0	0.5	138.0	3.5	144.0	143.0		143.5	1.0	0.5	+2.0	−2.5
									AVE.: WITHIN SINGLE SITTINGS					144.0	0.8	0.4		5.5				146.0	4.0	1.8	+2.5	0
									RANGE: BETWEEN DIFFERENT SITTINGS					5.0								6.5				
									MEAN DEV.: BETWEEN SITTINGS					2.5								2.8				
97	PRE		130.0	130.0		130.0	0	0	129.0	1.0																
	POST 1 mo.	PRE FU/FL																	135.0	135.0	134.5	135.0	0.5	0.2		+5.0
	2 mo.																		133.0	133.5	134.0	133.5	1.0	0.3		+3.5
	3½ mo.																		135.5	137.0	136.5	136.5	1.5	0.5		+6.5
	5 mo.																		137.5	137.0		137.5	0.5	0.2		+7.5
																			133.0	135.5		134.5	1.5	0.8		+4.5
	1 yr.	POST 6 mo.									132.0	134.0		133.0	2.0	1.0	131.0	2.0	131.5	132.5		132.0	1.0	0.5	−1.0	+2.0
									AVE.: WITHIN SINGLE SITTINGS													134.8	1.0	0.4	−1.0	+4.8
									RANGE: BETWEEN DIFFERENT SITTINGS													5.5				
									MEAN DEV.: BETWEEN SITTINGS													1.4				
98	PRE		141.0	141.0		141.0	0	0	140.0	1.0																
	POST 1 wk.	PRE FU/PL																	143.0	143.5	143.5	143.5	0.5	0.2		+2.5
	3 wk.																		143.5	144.0	145.0	144.0	1.5	0.5		+3.0
	1½ mo.																		144.5	145.0	145.0	145.0	0.5	0.2		+4.0
	3 mo.																		141.5	142.5	141.0	141.5	1.5	0.5		+0.5
	3½ mo.																		140.5	140.5	142.0	141.0	1.5	0.7		0
	11½ mo.	POST 7½ mo.									145.0	144.5		144.5	0.5	0.2	144.0	0.5	142.5	141.5		142.0	1.0	0.5	−2.5	+1.0
									AVE.: WITHIN SINGLE SITTINGS													142.8	1.1	0.4	−2.5	+1.8
									RANGE: BETWEEN DIFFERENT SITTINGS													4.0				
									MEAN DEV.: BETWEEN SITTINGS													1.3				

101	PRE		130.0	129.5		130.0	0.5	0.2	127.0	3.0											128.5	126.5	128.5	128.0	2.0	0.9		−2.0
	POST 1 mo.	PRE FU/PL																			128.0	127.0	127.5	127.5	1.0	0.3		−2.5
	1½ mo.																				130.0	129.0	129.0	129.0	1.0	0.4		−1.0
	3½ mo.																											
	5 mo.	POST 2 wk.									132.0	133.5		132.5	1.5	0.8	130.0	2.5	128.5	128.0		128.5	0.5	0.2	−4.0	−1.5
	6 mo.	1½ mo.									130.5	130.5	130.5														
											131.0			130.5	0.5	0.2	130.0	0.5	127.5	127.0		127.5	0.5	0.2	−3.0	−2.5
	8 mo.	3½ mo.									129.5	129.5		129.5	0	0	129.5	0	129.0	124.0		126.5	5.0	2.5	−3.0	−3.5
	14 mo.	9½ mo.									129.0	129.0		129.0	0	0	128.0	1.0	129.0	127.0		128.0	2.0	1.0	−1.0	−1.5
									AVE.: WITHIN SINGLE SITTINGS					130.4	0.6	0.3		1.0				127.9	1.7	0.8	−2.8	−2.1
									RANGE: BETWEEN DIFFERENT SITTINGS					3.5								2.5				
									MEAN DEV.: BETWEEN SITTINGS					1.1								0.8				
103	PRE	PRE FU/PL	133.5	133.5		133.5	0	0	132.0	1.0																	
	PRE		134.5	136.0		135.0	1.5	0.8	132.0	3.0																	
	PRE (AVE.)					134.5			132.0	2.5																	
	POST 3 da.	POST 3 da.									134.0	133.0		133.5	1.0	0.5	131.5	2.0	134.5	134.5		134.5	0	0	+1.0	0
	9½ mo.	9½ mo.									134.0	135.0		134.5	1.0	0.5	129.5	5.0	135.5	136.0		136.0	0.5	0.2	+1.5	+1.5
		POST Rebase															131.0										
									AVE.: WITHIN SINGLE SITTINGS					134.0	1.0	0.5		3.5				135.3	0.3	0.1	+1.3	+0.8
									RANGE: BETWEEN DIFFERENT SITTINGS					1.0								1.5				
									MEAN DEV.: BETWEEN SITTINGS					0.5								0.8				
104	PRE		128.0	129.0		128.5	1.0	0.5	127.0																		
									127.0	1.5																	
	POST 1 wk.	PRE FU/PL																	135.0	131.0	136.0	134.0	5.0	2.0		+5.5
	2 mo.																		131.0	130.0	132.0	131.0	2.0	0.7		+2.5
	4 mo.	Insertion									133.0	133.0		133.0	0	0	133.0	0	135.5	131.5		133.5	4.0	2.0	+0.5	+5.0
	14 mo.	POST 10 mo.									130.5	131.0		131.0	0.5	0.2	130.0	1.0	130.5	132.5		131.5	2.0	1.0	+0.5	+3.0
									AVE.: WITHIN SINGLE SITTINGS					132.0	0.3	0.1		0.5				132.5	3.5	1.4	+0.5	+4.0
									RANGE: BETWEEN DIFFERENT SITTINGS					2.0								3.0				
									MEAN DEV.: BETWEEN SITTINGS					1.0								1.3				
105	PRE		69.0	69.0		69.0	0	0	67.5	1.5																	
	PRE		69.0	69.5		69.5	0.5	0.2	67.5	2.0																	
					Ave.	69.0			67.5	1.5																	
	POST 2 wk.	PRE FU/PL																	67.5	68.5	69.5	68.5	2.0	0.7		−0.5
	1 mo.	POST 3 da.									69.5	69.5		69.5	0	0	69.5	0	71.5	71.0		71.0	0.5	0.2	+1.5	+2.0
	1½ mo.	POST Grind-in									69.0	70.0		69.5	1.0	0.5	68.5	1.0	72.0	72.0		72.0	0	0	+2.5	+3.0
	6 mo.	POST 5 mo.									69.0	69.5		69.0	0.5	0.2	67.5	1.5	70.0	70.0		70.0	0	0	+1.0	+1.0
	13 mo.	12 mo.									67.5	67.0		67.0	0.5	0.2	66.5	0.5	69.5	69.5		69.5	0	0	+2.5	+0.5
																			70.0	71.0	71.0	71.0	1.0	0.4	+4.0	+2.0
	13½ mo.	POST REBASE									70.0	69.5		69.5	0.5	0.2	69.0	0.5	70.0	70.0		70.0	0	0	+0.5	+1.0
	14 mo.	POST 13 mo.									70.0	70.0		70.0	0	0	69.0	1.0	71.5	71.5		71.5	0	0	+1.5	+2.5
									AVE.: WITHIN SINGLE SITTINGS					69.1	0.4	0.2		0.8				70.9	0.4	0.2	+1.9	+1.4
									RANGE: BETWEEN DIFFERENT SITTINGS					3.0								3.5				
									MEAN DEV.: BETWEEN SITTINGS					0.7								0.9				
107	PRE		90.5	90.5		90.5	0	0	90.5	0																	
	POST 5 mo.	PRE FU/PL																	87.5	87.5	88.5	88.0	1.0	0.4		−2.5
	11½ mo.																		87.0	87.5	88.0	87.5	1.0	0.3		−3.0
	12 mo.																		89.0	88.5	88.0	88.5	1.0	0.3		−1.5
									AVE.: WITHIN SINGLE SITTINGS													88.2	1.0	0.3		−2.3
									RANGE: BETWEEN DIFFERENT SITTINGS													1.0				
									MEAN DEV.: BETWEEN SITTINGS													0.6				

CASE NO.	TIME RELATIVE TO EXTRACTION OF OCCLUSAL STOPS	TIME RELATIVE TO RESTORATION WITH:	PRE-EXTRACTION VERTICAL DIMENSION								POST-EXTRACTION VERTICAL DIMENSION														DIFFERENCE BETWEEN REST WITH AND REST WITHOUT DENTURES	DIFFERENCE BETWEEN PRE-EXTRACTION REST WITH TEETH AND POST-EXTRACTION REST WITHOUT DENTURES
			REST (WITH NATURAL TEETH)								REST (WITH DENTURES)								REST (WITHOUT DENTURES)							
			I	II	III	AVE.	RANGE	MEAN DEV.	OCCLUSAL	FREE-WAY SPACE	I	II	III	AVE.	RANGE	MEAN DEV.	OCCLUSAL	FREE-WAY SPACE	I	II	III	AVE.	RANGE	MEAN DEV.		
109	PRE	PRE FU/FL	127.0	126.5		127.0	0.5	0.2	124.0	3 0																
			127.5	125.0		126.5	2.5	1.3																		
					Ave.	126.5				2.5																
	POST 5 mo.	POST 2 mo.									124.5	124.5		124.5	0	0	120.5	4.0	125.0	125.0		125.0	0	0	+0.5	−2.0
	10 mo.	7 mo.									123.5	125.5		124.5	2.0	1.0	120.5	4.0	124.0	125.0		124.5	1.0	0.5	0	−2.5
									AVE.: WITHIN SINGLE SITTINGS					124.5	1.0	0.5		4.0				124.8	0.5	0.3	+0.3	−2.3
									RANGE: BETWEEN DIFFERENT SITTINGS					0								0.5				
									MEAN DEV.: BETWEEN SITTINGS					0								0.3				
110	PRE		149.0	148.5	148.0	148.5	1.0	0.3	143.5																	
									143.5	5.0																
	POST 3 wk.	PRE FU/FL																	145.0	145.5	146.0	145.5	1.0	0.3		−3.0
	5 wk.																		143.5	144.5		144.0	1.0	0.5		−4.5
	3 mo.	Insertion									146.0	147.0		146.5	1.0	0.5	146.0	0.5	147.5	146.5		147.0	1.0	0.5	+0.5	−1.5
	4 mo.	POST 1 mo.									145.5	146.5		146.0	1.0	0.5	144.5	1.5	146.0	146.5		146.5	0.5	0.2	+0.5	−2.0
	11 mo.	8 mo.									143.0	144.0		143.5	1.0	0.5	141.0	2.5	142.5	141.5		142.0	1.0	0.5	−1.5	−6.5
	14 mo.	11 mo.									145.5	144.5		145.0	1.0	0.5	141.0	4.0	142.0	142.0		142.0	0	0	−3.0	−6.5
									AVE.: WITHIN SINGLE SITTINGS					145.2	1.0	0.5		2.1				144.5	0.7	0.3	−0.9	−4.0
									RANGE: BETWEEN DIFFERENT SITTINGS					3.0								5.0				
									MEAN DEV.: BETWEEN SITTINGS					1.0								1.8				
113	PRE		144.5	145.5	145.0	145.0	1.0	0.3	141.5	3.5																
	POST 2 wk.	PRE FU/PL																	145.5	145.0	145.5	145.5	0.5	0.2		+0.5
	6 wk.																		145.0	146.5		145.5	1.5	0.8		+0.5
	7 wk.																		142.0	142.0		142.0	0	0		−3.0
	9 wk.	Set-up															142.0		145.0	145.0		145.0	0	0		0
	3 mo.	Insertion									142.0	142.5		142.5	0.5	0.2	142.0	0.5	145.0	146.0		145.5	1.0	0.5	+3.0	+0.5
	11½ mo.	POST Rebase									144.0	144.0		144.0	0	0	143.0	1.0	145.0	145.0		145.0	0	0	+1.0	0
									AVE.: WITHIN SINGLE SITTINGS					143.3	0.3	0.1		0.8				144.7	0.5	0.3	+2.0	−0.3
									RANGE: BETWEEN DIFFERENT SITTINGS					1.5								3.5				
									MEAN DEV.: BETWEEN SITTINGS					0.8								0.9				
114	PRE		129.0	129.0		129.0	0	0	129.0	0																
	Immediate	Insertion FU									132.0	134.0		133.0	2.0	1.0	132.0	1.0	131.5	131.5		131.5	0	0	−1.5	+2.5
	POST 7 mo.	POST 7 mo.									133.5	132.5		133.0	1.0	0.5	130.5	2.5	134.5	132.5		133.5	2.0	1.0	+0.5	+4.5
	10½ mo.	POST Rebase									135.0	134.5		135.0	0.5	0.2	133.0	2.0	131.5	132.5		132.0	1.0	0.5	−3.0	+3.0
									AVE.: WITHIN SINGLE SITTINGS					133.7	1.2	0.6		1.8				132.3	1.0	0.5	−1.3	+3.3
									RANGE: BETWEEN DIFFERENT SITTINGS					2.0								2.0				
									MEAN DEV.: BETWEEN SITTINGS					0.9								0.8				
116	PRE	PRE FU/FL	128.0	129.0		128.5	1.0	0.5	126.5	2.0																
	POST 2 mo.	Insertion									125.5	125.0		125.0	0.5	0.2	125.0	0	123.0	123.5		123.5	0.5	0.2	−1.5	−5.0
	2¼ mo.	POST 1 wk.									127.0	127.0		127.0	0	0	124.0	3.0	125.0	125.0		125.0	0	0	−2.0	−3.5
	9½ mo.	7½ mo.									127.0	127.5		127.5	0.5	0.2	123.0	4.5	124.0	124.0		124.0	0	0	−3.5	−4.5
									AVE.: WITHIN SINGLE SITTINGS					126.5	0.3	0.1		2.5				124.2	0.2	0.1	−2.3	−4.3
									RANGE : BETWEEN DIFFERENT SITTINGS					2.5								1.5				
									MEAN DEV.: BETWEEN SITTINGS					1.0								0.6				

118	PRE		126.5	127.0		127.0	0.5	0.3	124.0	3.0															
	POST 3 wk.	PRE FU/FL																	123.0	123.0	123.0	123.0	0	0		−4.0
	2 mo.	Set-up														122.0			121.5	121.5		121.5	0	0		−5.5
	2¼ mo.	POST 1 da.									124.0	124.0	124.0	0	0	124.0	0		122.5	123.0		123.0	0.5	0.2	−1.0	−4.0
	3 mo.	3 wk.									122.0	122.5	122.0	0.5	0.3	122.0	0		120.5	119.5		120.0	1.0	0.5	−2.0	−7.0
																			121.5	121.0		121.5	0.5	0.2	−0.5	−5.5
	12 mo.	10 mo.									118.5	118.0	118.5	0.5	0.3	118.0	0.5		119.0	119.0		119.0	0	0	+0.5	−8.0
									AVE.: WITHIN SINGLE SITTINGS				121.5	0.3	0.2		0.2					121.2	0.3	0.2	−0.8	−5.8
									RANGE: BETWEEN DIFFERENT SITTINGS				5.5									4.0				
									MEAN DEV.: BETWEEN SITTINGS				2.0									1.3				
151	PRE		126.5	126.5		126.5	0	0	126.0	0.5																
	POST 2 wk.	PRE FU/FL																	129.5	129.0	129.5	129.5	0.5	0.2		+3.0
	6 wk.																		125.0	125.5	125.5	125.5	0.5	0.2		−1.0
	4 mo.	POST 1 mo.									131.5	131.5	131.5	0	0	131.0	0.5		125.0	125.5		125.5	0.5	0.2	−5.5	−1.0
																			125.5	125.5		125.5	0	0	−5.5	−1.0
	10½ mo.	7½ mo.														127.5			124.5	125.5		125.0	1.0	0.5		−1.5
									AVE.: WITHIN SINGLE SITTINGS													126.2	0.5	0.2	−5.5	−0.3
									RANGE: BETWEEN DIFFERENT SITTINGS													4.5				
									MEAN DEV.: BETWEEN SITTINGS													1.2				
153	PRE		138.5	138.0		138.0	0.5	0.3	137.5	0.5																
	POST 2 mo.	PRE FU/FL																	134.0	135.0	133.5	134.0	1.5	0.5		−4.0
	3 mo.																		134.5	134.5	134.0	134.5	0.5	0.2		−3.5
	3½ mo.																		136.5	135.5	137.0	136.5	1.5	0.5		−1.5
	4 mo.																		136.0	134.0		135.0	2.0	1.0		−3.0
	4½ mo.																		134.0	133.5	132.5	133.5	1.5	0.5		−4.5
	12 mo.	POST 7 mo.									137.0	137.5	137.0	0.5	0.2	137.0	0		132.0	131.5	131.5	131.5	0.5	0.2	−5.5	−6.5
									AVE.: WITHIN SINGLE SITTINGS													134.2	1.5	0.5	−5.5	−3.8
									RANGE: BETWEEN DIFFERENT SITTINGS													5.0				
									MEAN DEV.: BETWEEN SITTINGS													1.1				

TOOTH MOBILITY CHANGES DURING TREATMENT WITH PARTIAL DENTURE PROSTHESIS

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WEARING A REMOVABLE PARTIAL denture prosthesis of any type may be beneficial and/or detrimental to the remaining periodontal structures as the case may be. Prosthodontics is one of the means of establishing conditions for the maintenance of periodontal health. Inadvertently, it may also contribute to the initiation and progress of periodontal disease. It is assumed that horizontal and lateral stress on abutment teeth, among other etiologic factors, may cause or favor the breakdown of periodontal structures.

Various clasps have been designed for the retention and proper function of partial denture prosthesis. It is not the intention of the authors to review and discuss the literature on the different modes of retention of removable partial denture prosthesis. The main principle of clasp construction is to direct the external masticatory and oral muscle forces along the long axes of abutment teeth. Broken-stress attachments are also used in order to avoid trauma by distributing the load of the denture between the teeth and the mucosa.

The modified pattern of force distribution on abutment teeth due to the insertion of partial denture prosthesis has never been investigated under in vivo conditions. The mode of transmission of masticatory and other oral forces on the periodontium by various clasps is assumed on the basis of the laws of general mechanics and laboratory experiments.

This article is an attempt in the field of *experimental prosthetics*. It has been shown in previous studies[1-3] that there is a close relationship between the degree of tooth mobility and undue periodontal stress. Undue mechanical stress induces an increase in the mobility of traumatized teeth. It seemed to be of some interest to study the mobility changes of abutment teeth of patients being treated with lower partial denture prosthesis.

METHOD AND MATERIAL

Tooth mobility (TM) measurements of the instantaneous total crown excursion (the crowns of abutment teeth being loaded 2 to 3 seconds with a 500 Gm. force) were made by a *microdial indicator* (Fig. 1,*A*) with a special *acrylic resin holding* apparatus (Fig. 1,*B*); the latter fixing the measuring gauge intraorally. Details concerning the measuring procedure have been reported elsewhere.[4]

Received for publication Dec. 6, 1955.

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One hundred and seventy-eight tooth mobility measurements were made during seven months on 8 abutment teeth (lower canines) of four male patients, 38 to 73 years of age (A.H., B.H., W.E., T.K.). The remaining dentition of these patients was 321-123. After a pre-experimental (pre-prosthetic) period of observation, all of the patients were treated with an upper complete denture and at

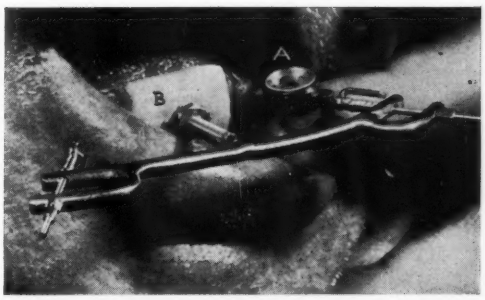


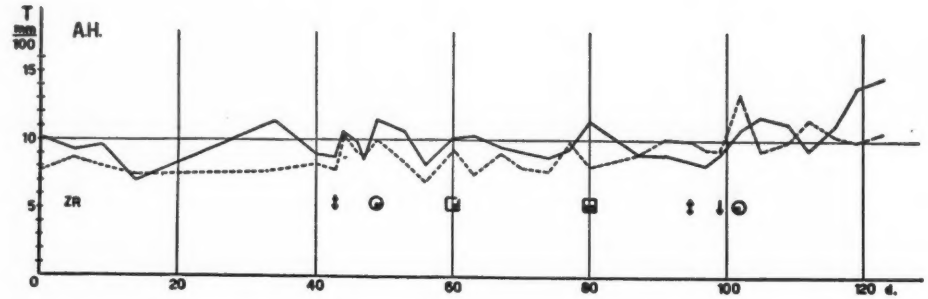
Fig. 1.—*A*, The dial-indicator adapted to the lower left cuspid. This tooth is moved to the labial and lingual with a known force (forcemeter) and the amount of instantaneous total crown excursion is read on the dial. *B*, The individual acrylic resin holding apparatus.

A. *B.*

Fig. 2.—*A*, The clasp with a lug rest used during the first experimental period. *B*, The elastic wire clasp used during second experimental period.

the same time with a lower partial denture prosthesis. During the *first experimental period* (1. exp.p.), the lower prosthesis was anchored to the canine abutments with nonelastic cast clasps with lug rests (Fig. 2,*A*). After two months the partial denture was removed for about seven days, during which time the nonelastic clasps were exchanged by elastic wire clasps without occlusal lug rests (Fig. 2,*A*). The partial denture was then reinserted for a *second experimental period* (2. exp.p.). Care was taken that both lower partial denture constructions were identical in all respects except clasp design. Tooth mobility was measured at regular intervals before and during the first and second experimental periods.

Fig. 3.



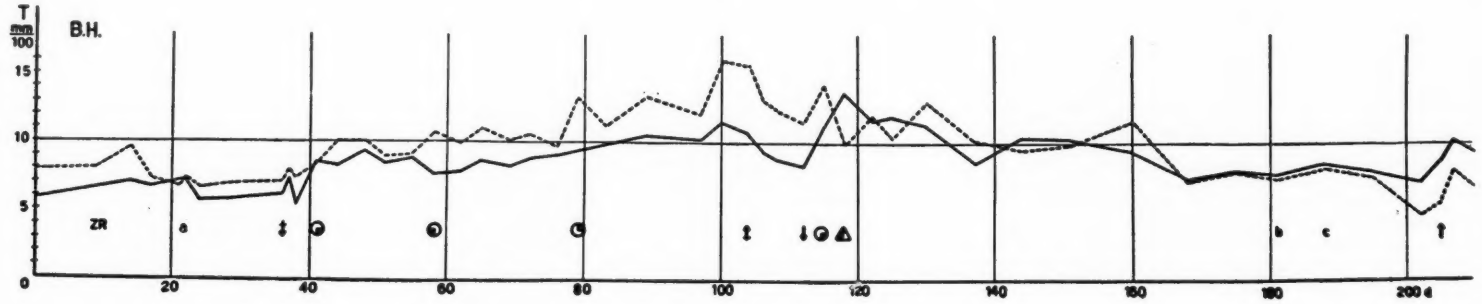


Fig. 4.

Figs. 3-6.—Graphs of the mobility of the abutment teeth. T = Total crown excursion in mm. × 10^{-2} when a 500 Gm. force is applied to the crown; d = days; ..... left abutment tooth; ——— right abutment tooth; ↕ insertion of prosthesis (first experimental period); ↕ removal of prosthesis (first experimental period); ↓ insertion of prosthesis (second experimental period); ↑ removal of prosthesis (second experimental period); ○ sore spots (in the four quadrants); □ rebasing (in the four quadrants); △ soreness of abutment tooth.

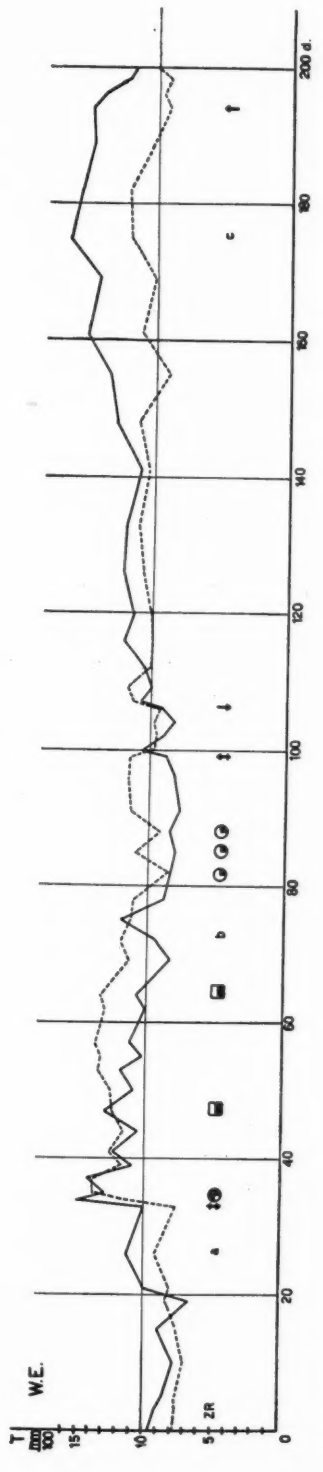

W.E.
T
mm
100
ZR
0
5
10
15
20
40
60
80
100
120
140
160
180
200 d.
a
b
c

Fig. 5.

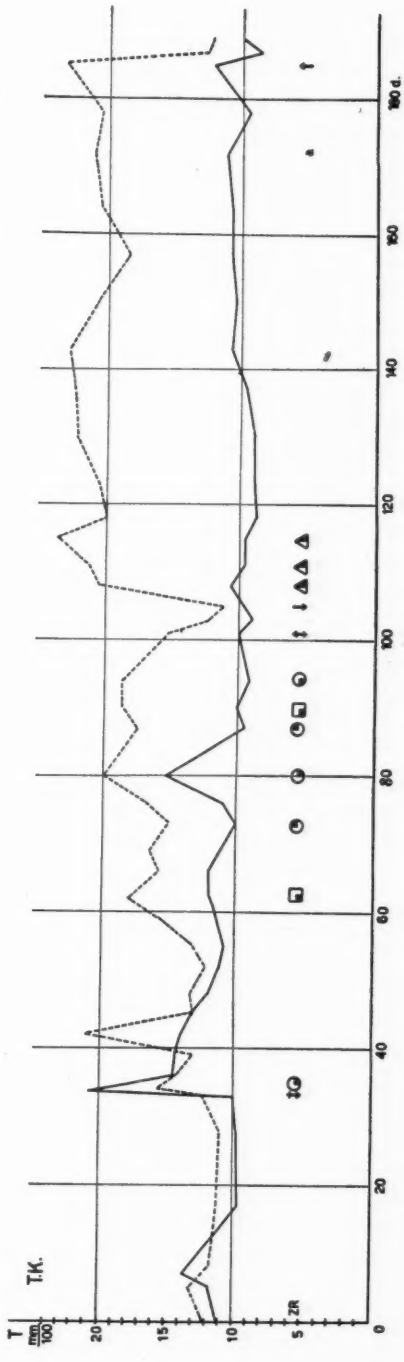

T.K.
T
mm
100
ZR
0
5
10
15
20
40
60
80
100
120
140
160
180 d.
a

Fig. 6.

RESULTS

The changes in tooth mobility (T_{500})* in all four patients are summarized in Figs. 3 to 6. Mobility values on the ordinate are plotted against time (days) on the abscissa.

1. The pre-experimental TM-determinations on all eight abutment teeth showed mobility levels ranging between 0.05 and 0.12 mm.

2. During the pre-experimental or pre-prosthetic period there were some mobility fluctuations, the greatest difference being 0.05 mm.

3. Treatment by partial denture prosthesis produced both *acute and gradual TM-changes on both or on only one of the two abutment teeth.*

Acute Mobility Changes.—

A. *Insertion of partial prosthesis:* In some but not all abutment teeth, acute mobility changes occurred immediately after the insertion of the prosthesis. (See Figs. 5 and 6, Case W.E., 1. exp.p., Case T.K.) Mobility increased as much as 0.11 mm. or 110 per cent. These initial mobility increments were either of short duration (Case T.K., 1. exp.p.), or of long duration (Case W.E., 1. exp.p., Case T.K., 2. exp.p.).

In many instances, the insertion of the prosthesis produced no immediate mobility increments.

B. *Removal of partial prosthesis:* In those cases where the mobility level was higher than in the pre-prosthetic period, removal of partial prosthesis was followed by an immediate decrease in mobility (See Figs. 4, 5, 6, Case W.E., T.K., B.H., 1. exp.p.).

In one case, the removal of the partial denture led to a consequent increase in mobility of the abutment teeth (See Fig. 4, Case B.H., 2. exp.p.).

C. *Acute mobility changes during prosthesis wearing:* During treatment with partial denture prosthesis, mobility fluctuations were observed. They were, in some cases, not greater than those during the pre-experimental period. In other teeth, they were more pronounced.

In most instances they coincided with the appearance of denture sores and with rebasing procedures.

Gradual Mobility Changes.—

A trend to gradual mobility changes was found in other abutment teeth. In cases W.E. (2. exp.p.), B.H. (1. exp.p.) mobility did not increase acutely but gradually during several weeks after denture insertion (Figs. 5, 6). Case W.E. (1. exp.p.) showed a gradual decrease of high mobility values that had been produced by the previous denture insertion (Fig. 5).

4. No striking differences in mobility changes could be found in comparing the first and second experimental period. It appears that the patients treated with nonsettling lug rest clasps had somewhat smaller mobility disturbances, but the smallness of the sample does not permit any definite conclusions.

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*Total crown excursion when produced with a 500 Gm. force.

DISCUSSION AND SUMMARY

It has been shown that significant acute or gradual tooth mobility changes were produced by treatment with partial denture prosthesis. They were different in magnitude, in duration, in maintenance, and in localization to the abutment teeth during the total 200-day experimental period.

It is assumed that future experiments in the suggested line may yield valuable scientific information about the periodontal reaction of abutment teeth to the forces produced and transmitted by prosthetic appliances. On the other hand, the changes in mobility testing consecutively different experimental prosthetic appliances on the same patient may be used as an indicator of the degree of periodontal trauma by prosthetic treatment.

We wish to express our gratitude to Dr. C. M. E. Eugster, D.D.S., L.D.S., R.C.S., for assistance in translation.

REFERENCES

1. Mühlemann, H. R.: Tooth Mobility (V). Tooth Mobility Changes Through Artificial Trauma, J. Periodont. **25**:202-208, 1954.
2. Mühlemann, H. R., Hirt, H., and Herzog, H.: Tooth Mobility—Bruxism—Selective Grinding, Proc. Int. A.R.P.A. Congress, Venice, 1955.
3. Hirt, H., and Mühlemann, H. R.: Diagnosis of Bruxism by Means of Tooth Mobility Measurements, Parodontologie **9**:47, 1955.
4. Mühlemann, H. R.: Tooth Mobility. The Measuring Method, Initial and Secondary Tooth Mobility. J. Periodont. **25**:22-29, 1954.

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EFFECT OF PARTIAL DENTURE DESIGN ON UNILATERAL FORCE DISTRIBUTION

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THE EFFECT OF PARTIAL denture design on bilateral force distribution has been studied in its relation to the movement of the abutment teeth and related simulated resilient tissues.[1] Known forces were imparted to a test partial denture in which the extensive stress distribution principle was employed, by means of a lever of the third class and weights. Distribution of the forces was accomplished by means of a bilateral jig.

In this study, consideration was given to the distribution of these same forces to the edentulous side only by means of a unilateral jig. The objective was to study the effect of partial denture design on *unilateral* force distribution in its relation to the movement of the abutment teeth and related simulated resilient tissues. The same test partial denture was used as in the previous study,[1] and with the same modifications.

TESTING PROCEDURE

For each modification, a unilateral jig was used instead of a bilateral jig, but the testing procedures were the same. The unilateral jig consisted of a metallic base, comparable to a mounting ring in its positioning, with two square rods held in place by Allen set screws. The lower end of each rod was embedded in an acrylic resin tooth that had been previously occluded with its opposing member on the partial denture. The teeth were equilibrated for occlusal harmony in centric and eccentric excursions by grinding, and the rods made secure in their respective positions by tightening the Allen set screws.

Magnified movements of the three abutment teeth were projected upon a screen by a means of a modified Beseler opaque projector, and plotted on graph paper in centric, protrusive, right, and left lateral positions. Vertical and horizontal components of stress distribution were read directly from three dial indicators (Fig. 1).

Compilation of data obtained required interpretation of all six related recordings as a *unit*. The direction and amount of movement of the three abutment teeth were interrelated with the measurements derived from the three dial indicators in order to evaluate the effect of partial denture design on unilateral force distribution (Figs. 2, 3, and 4). All modifications to the partial denture, for these comparative studies, could be valid only when the modification under consideration was compared to a previous modification.

The opinions or assertions contained herein are those of the author and are not to be construed as official or as reflecting the view of the Navy Department or the Naval Service at large.

Received for publication July 11, 1955; revised by the author Oct. 25, 1955.

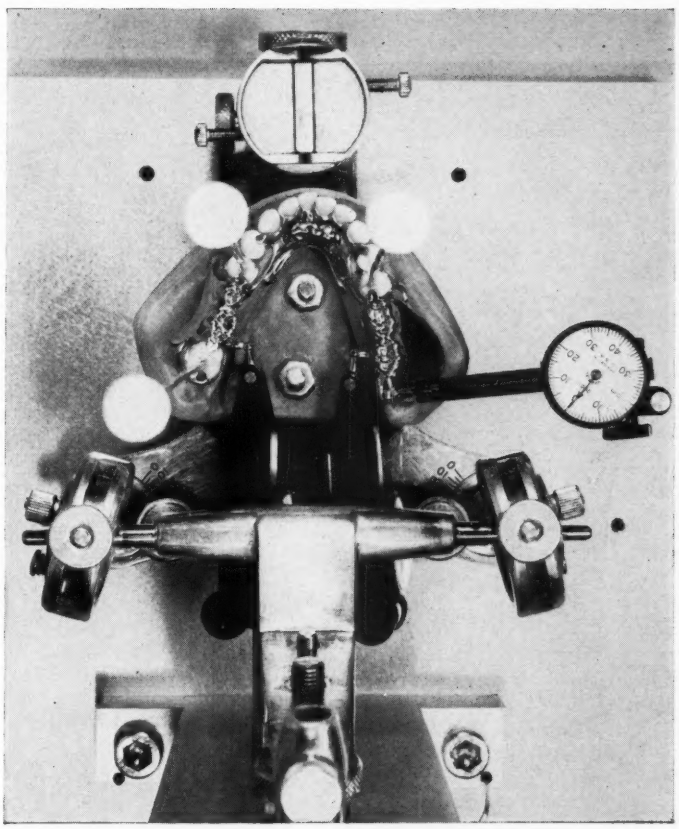

Fig. 1.—The dial indicators in position at the provided measuring sites.

Fig. 2.

Fig. 3.

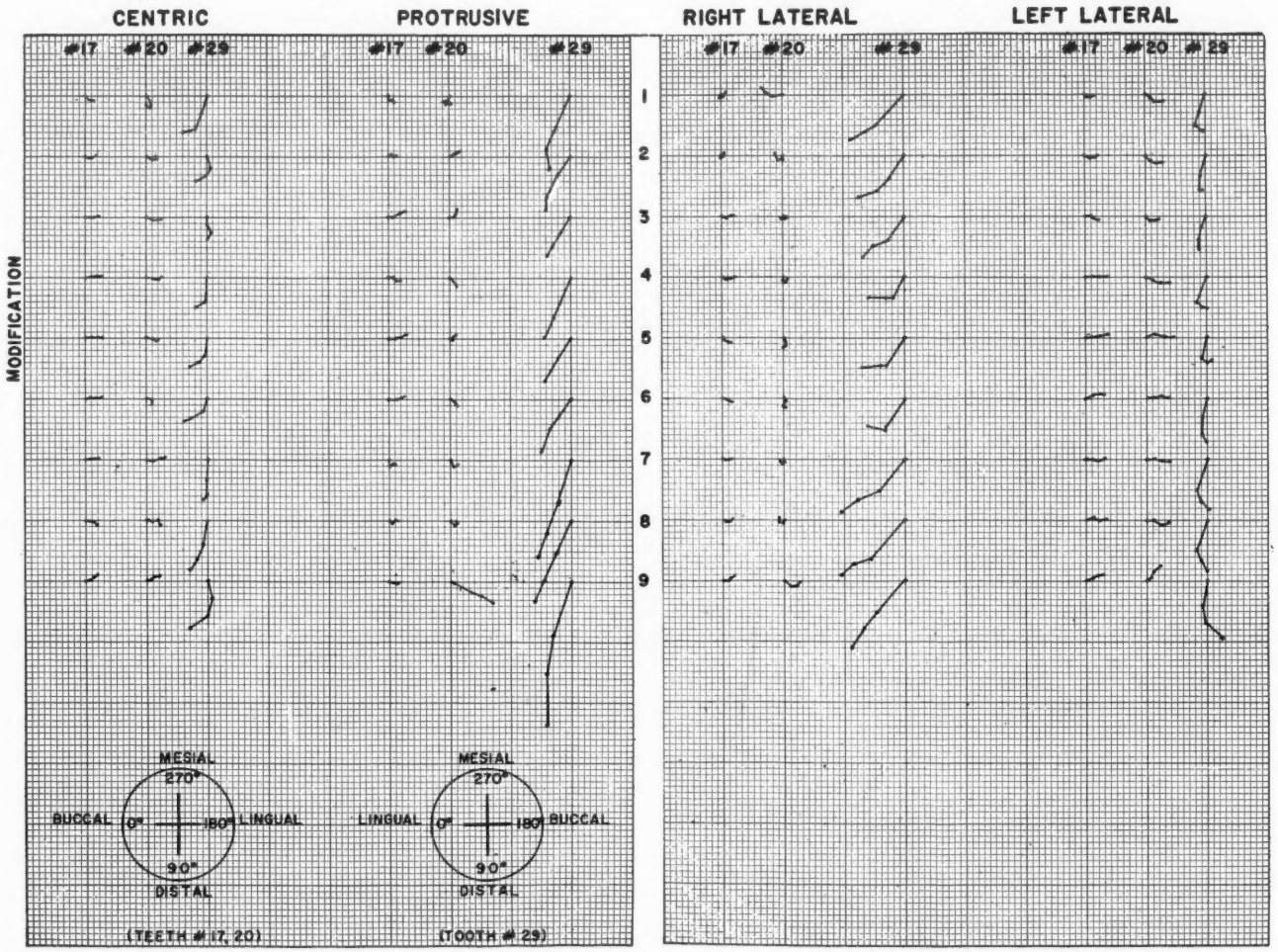

Fig. 4.

Fig. 2.—The dial indicator measurements of the vertical component (free end saddle).
Fig. 3.—The lingual dial indicator measurements of the horizontal components.
Fig. 4.—A composite presentation of abutment tooth movement for comparative study. The left third molar is designated as tooth No. 17, the left second bicuspid as tooth No. 20, and the right second bicuspid as tooth No. 29.

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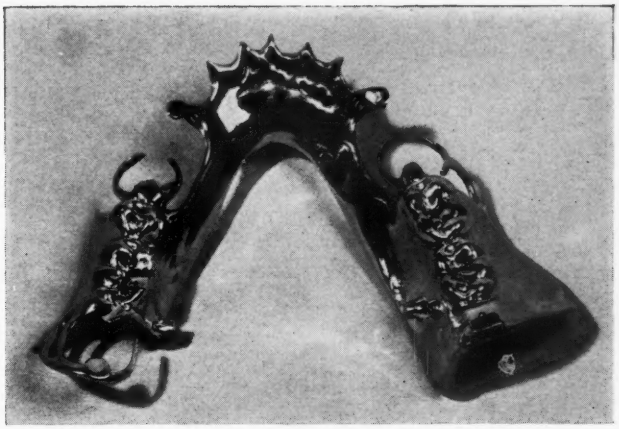

Fig. 5.—The test partial denture as it was designed originally.

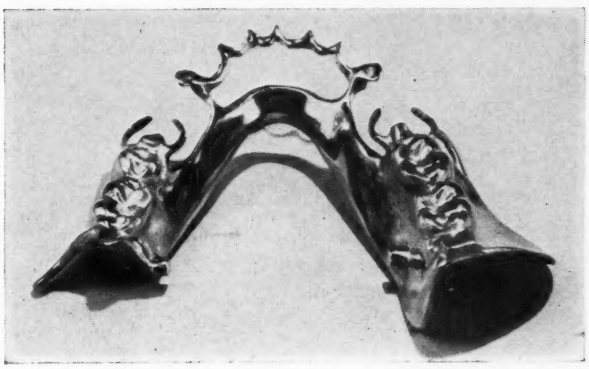

Fig. 6.—The lingual plate altered to become a continuous bar retainer.

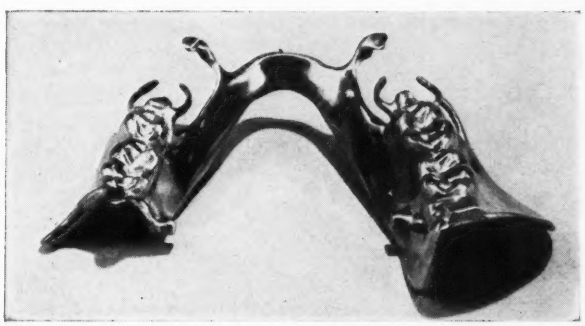

Fig. 7.—The continuous bar retainer was removed.

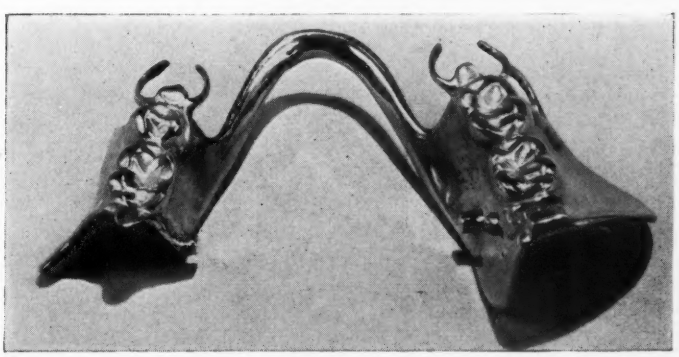

Fig. 8.—The rigid lingual bar was reduced so it would be a flexible bar.

SUMMARY OF FINDINGS

1. The partial denture as it was designed originally is shown in Fig. 5.

Measurements were made and recorded. These measurements were later compared with the measurements obtained upon modification of the partial denture.

	MODIFICATIONS								
	1	2	3	4	5	6	7	8	9
Centric									
10 lb.	.0042″	.0030″	.0035″	.0050″	.0050″	.0040″	.0040″	.0040″	.0050″
20 lb.	.0085	.0075	.0080	.0095	.0095	.0090	.0085	.0105	.0100
30 lb.	.0125	.0110	.0120	.0130	.0135	.0125	.0125	.0140	.0150
Protrusive									
10 lb.	.0050	.0050	.0050	.0060	.0065	.0065	.0050	.0050	.0070
20 lb.	.0090	.0085	.0080	.0100	.0100	.0105	.0080	.0080	.0125
30 lb.	.0125	.0115	.0110	.0135	.0130	.0135	.0105	.0105	.0180
Right lateral									
10 lb.	.0065	.0050	.0060	.0065	.0070	.0070	.0055	.0060	.0080
20 lb.	.0100	.0090	.0090	.0100	.0100	.0105	.0090	.0095	.0130
30 lb.	.0130	.0120	.0120	.0130	.0130	.0135	.0120	.0120	.0185
Left lateral									
10 lb.	.0045	.0050	.0045	.0070	.0070	.0060	.0065	.0065	.0070
20 lb.	.0090	.0095	.0090	.0105	.0110	.0110	.0100	.0100	.0120
30 lb.	.0120	.0125	.0140	.0140	.0140	.0145	.0135	.0130	.0165

2. The reinforced buccal arm was removed from the ring clasp.

Changes in direction of movement of the left third molar and left second bicuspid were noted in centric and protrusive positions.

The vertical dial indicator recorded relatively smaller recordings in all positions, except in the left lateral position. In the left lateral position, the recordings were larger. The lingual dial indicator measurements gave greater recordings in centric position. In the protrusive and right lateral positions, the recordings on both sides were found to be smaller. In the left lateral position no appreciable changes were noted.

The removal of the buccal arm from the ring clasp increased its flexibility allowing for the directional changes of movement of the left molar and left second bicuspid.

3. The ring clasp was removed.

The directional movement of the left second bicuspid was affected in centric, protrusive, right, and left lateral positions. No other appreciable changes were noted.

The vertical dial indicator recorded relatively greater measurements in centric and left lateral positions. Smaller measurements were noted in the protrusive position. In the right lateral position the measurements were about the same. The lingual dial indicator measurements were greater in centric, smaller in protrusive and left lateral positions. In the right lateral position, increased negative

	MODIFICATIONS									
	1		2		3		4		5	
Centric	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
10 lb.	—.0005″	.0009″	—.0006″	.0009″	—.0008″	.0012″	—.0009″	.0013″	—.0006″	.0008″
20 lb.	—.0010	.0011	—.0014	.0016	—.0019	.0025	—.0014	.0018	—.0015	.0016
30 lb.	—.0013	.0011	—.0019	.0018	—.0025	.0026	—.0018	.0019	—.0020	.0018
Protrusive										
10 lb.	—.0004	.0002	—.0004	.0002	—.0005	.0003	—.0002	.0002	—.0002	.0000
20 lb.	—.0010	.0003	—.0010	.0005	—.0010	.0004	—.0008	.0006	—.0009	.0002
30 lb.	—.0019	.0010	—.0017	.0010	—.0016	.0007	—.0014	.0007	—.0015	.0005
Right lateral										
10 lb.	.0001	—.0013	—.0002	—.0004	—.0004	—.0002	—.0001	—.0003	—.0001	—.0006
20 lb.	—.0001	—.0017	—.0003	—.0011	—.0006	—.0005	—.0005	—.0007	—.0003	—.0009
30 lb.	—.0005	—.0022	—.0004	—.0014	—.0009	—.0008	—.0008	—.0009	—.0006	—.0013
Left lateral										
10 lb.	—.0005	.0007	—.0006	.0007	—.0007	.0003	—.0005	.0004	—.0008	.0010
20 lb.	—.0013	.0014	—.0013	.0014	—.0015	.0010	—.0015	.0016	—.0019	.0023
30 lb.	—.0022	.0022	—.0022	.0023	—.0020	.0014	—.0023	.0024	—.0027	.0026

			6		7		8		9	
Centric			Left	Right	Left	Right	Left	Right	Left	Right
10 lb.	—	—	—.0006	.0007	—.0008	.0010	—.0007	.0005	—.0009	.0011
20 lb.	—	—	—.0011	.0011	—.0019	.0020	—.0016	.0011	—.0016	.0012
30 lb.	—	—	—.0017	.0013	—.0024	.0023	—.0017	.0014	—.0018	.0010
Protrusive										
10 lb.	—	—	—.0004	.0004	—.0001	.0004	—.0001	.0003	—.0005	.0001
20 lb.	—	—	—.0010	.0005	—.0010	.0008	—.0010	.0005	—.0009	—.0002
30 lb.	—	—	—.0014	.0007	—.0016	.0011	—.0015	.0007	—.0012	—.0005
Right lateral										
10 lb.	—	—	—.0001	—.0004	—.0001	—.0008	.0000	—.0014	—.0002	—.0017
20 lb.	—	—	—.0003	—.0007	—.0002	—.0016	—.0001	—.0018	—.0007	—.0029
30 lb.	—	—	—.0008	—.0009	—.0004	—.0021	—.0004	—.0021	—.0012	—.0035
Left lateral										
10 lb.	—	—	—.0007	.0007	—.0009	.0001	—.0008	.0001	—.0008	.0001
20 lb.	—	—	—.0014	.0017	—.0018	.0009	—.0018	.0013	—.0018	.0005
30 lb.	—	—	—.0024	.0026	—.0025	.0017	—.0025	.0017	—.0026	.0009

measurements on the left lingual flange were obtained with decreased negative measurements on the right lingual flange.

On the basis of the altered movement of the left second bicuspid and the dial indicator measurements, it appeared that a ring clasp is a desirable design in withstanding both vertical and horizontal stresses.

4. The lingual plate was altered to become a continuous bar retainer (Fig. 6).

The left second bicuspid manifested altered directional movement in the protrusive, right, and left lateral positions. The right second bicuspid showed a greater amount of movement in centric and protrusive positions. In the right lateral position, the right second bicuspid showed a change in directional movement.

The vertical dial indicator recorded generalized increases in all positions. The lingual dial indicators showed a change in the left lateral position with increased recordings on the right lingual flange and greater negative recordings on the left lingual flange. In the centric position, the recordings were smaller. In the protrusive and right lateral positions there were no appreciable changes.

A lingual plate appeared to add to the rigidity of the partial denture tending to reduce vertical and horizontal stresses.

5. The continuous bar retainer was removed (Fig. 7).

No marked changes were observed in abutment tooth movement.

The vertical dial indicator showed no marked changes. The lingual dial indicator measurements showed no marked changes in centric or protrusive positions. In the right and left lateral positions, the measurements were relatively larger.

Although no marked changes were observed in abutment tooth movement, the lingual dial indicator measurements in the right and left lateral positions seemed to indicate that the continuous bar retainer is important in resisting horizontal stresses.

6. The indirect retainers were removed.

The right second bicuspid displayed a greater amount of movement in protrusive and left lateral positions. No other appreciable changes in abutment tooth movement were observed.

The vertical dial indicator measurements were greater in the protrusive, right, and left lateral positions. In the centric position, the measurements were smaller. The lingual dial indicator measurements were smaller in centric and left lateral positions. In the protrusive position, the measurements were about the same. In the right lateral position, the left lingual flange showed increased negative measurements with decreased negative measurements on the right lingual flange.

Although there were no marked changes in abutment tooth movement, the vertical and horizontal dial indicator measurements appeared to indicate that indirect retainers have a direct influence on vertical and horizontal stresses.

7. The rigid lingual bar was reduced so it would be a flexible bar (Fig. 8).

The amount of movement of the right second bicuspid was noted particularly in the protrusive and right lateral positions. In the protrusive position, before the present modification, the calibrated horizontal force was 6 ounces. With the modification, the calibrated force was approximately 10 ounces. The direction of movement distolingually in both was relatively the same. In the right lateral position, before modification, the calibrated horizontal force was 4 ounces. After modification, the force was 8 ounces. Directional movement was also altered upon modification.

The vertical dial indicator measured smaller recordings in the protrusive, right, and left lateral positions. In the centric position, the measurements were approximately the same. The lingual dial indicator measurements showed increased measurements in centric, protrusive, and right lateral positions. In the left lateral position, the left lingual flange was relatively the same, but the right lingual flange displayed smaller recordings.

A rigid major connector appeared to be more desirable in withstanding horizontal and vertical stresses as evidenced by the movement of the right second bicuspid and the dial indicator measurements.

8. The left denture base was reduced.

No marked changes in abutment tooth movement were observed.

The vertical dial indicator measurements showed no marked changes except in centric position in which greater measurements were observed. The lingual dial indicator measurements showed no marked changes in right or left lateral positions. In centric and protrusive positions, the recordings were found to be smaller.

On the basis of abutment tooth movement and dial indicator measurements, no apparent difference was observed when the left denture base was reduced.

9. The right denture base was reduced.

The direction of movement of all abutment teeth was affected by this modification. The amount of movement of the abutment right second bicuspid manifested the greatest change. In the protrusive position, before modification, the calibrated horizontal force was 8 ounces. Upon reducing the right saddle, the amount of force was 10 ounces. The left second bicuspid also displayed a substantial amount of movement in the protrusive position.

The dial indicator primarily measuring vertical components of stress showed the greatest recordings for all positions. The lingual dial indicators measured bilateral negative recordings for both protrusive and right lateral positions. In centric and left lateral positions, the left lingual flange remained relatively the same, but the right lingual flange gave smaller recordings.

Maximum coverage of denture-bearing areas with large, wide denture bases extending posteriorly, buccally, and lingually consistent with the anatomic and physiologic limitations, appeared to be of the utmost importance in withstanding both vertical and horizontal components of stress.

CONCLUSIONS

The effect of partial denture design on unilateral force distribution was studied in its relation to the movement of abutment teeth and related simulated resilient tissues in which the extensive stress distribution principle was employed.

The conclusions of the unilateral study are similar to those found in the bilateral study: (1) A ring clasp should be reinforced with a buccal arm to reduce its flexibility. (2) A rigid lingual bar is more desirable than a flexible bar in withstanding horizontal stresses. (3) Maximum coverage of denture-bearing areas with large, wide denture bases is essential in withstanding both vertical and horizontal stresses. (4) No definite conclusions could be made relative to the other modifications considered other than that they are dependent upon the basic rigidity of the lingual bar.

Continued studies are necessary to further pursue the subtle ramifications of the effect of partial denture design on force distribution.

I wish to acknowledge indebtedness to Captain A. R. Frechette, (DC) USN, for his counsel and guidance, and to J. C. Thompson, B.S., F. D. Carpenter, B.S., J. H. Sneed, photographer, W. E. Gilbert, machinist, and others of the U.S. Naval Electronics Laboratory, San Diego, California, for their generous suggestions and invaluable technical assistance.

REFERENCES

1. Kaires, A. K.: Effect of Partial Denture Design on Bilateral Force Distribution, J. Pros. Den. **6**:373-385, 1956.

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ELASTIC PROPERTIES OF RUBBER BASE IMPRESSION MATERIALS

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A NEW OR IMPROVED impression technique must have as its foundation the utilization of mechanical and chemical properties of the impression material. Therefore, with the introduction of a new type of impression material considerable information must be obtained about these properties in order that the material may be applied to its best advantage in the dental technique.

SETTING REACTION

Rubber base impression materials, although new in dentistry, have found industrial applications for several years. Their chemistry has been described in commercial literature.[1] The average structure is:

$HS\text{-}(C_2H_4\text{-}O\text{-}CH_2\text{-}O\text{-}C_2H_4\text{-}S\text{-}S)_{23}\text{-}C_2H_4\text{-}O\text{-}CH_2\text{-}O\text{-}C_2H_4\text{-}SH$

or $HS\text{-}(R\text{-}SS)_{23}\text{-}R\text{-}SH$

These materials are classified as Thiokol liquid polymers, and their setting reaction occurs by further condensation polymerization. The two terminal mercaptan groups, -SH, are the functional groups as far as the polymerization is concerned.[2]

Rapid polymerization is induced by addition of lead peroxide and sulfur suspensions in the dental impression materials, and stearic acid may be added as a retarder in order to control the working time.

In the dental impression materials of this type the setting reaction is assumed to take place in two steps:

(1) $2HS\text{-}(RSS)_{23}R\text{-}SH + PbO_2 \longrightarrow \text{-}S(RSS)_{22}RS\text{-}Pb\text{-}SR(SSR)_{23}S\text{-} + 2H_2O$

(2) $\text{-}S(RSS)_{23}RS\text{-}Pb\text{-}SR(SSR)_{23}S\text{-} + S \xrightarrow{R.T.} \text{-}S(RSS)_{23}RSSR(SSR)_{23}S\text{-} + PbS$

The Thiokol polymer is a viscous liquid which when mixed with the accelerators changes into an elastic end product. The process is irreversible.

For dental use the rubber base impression materials are in most instances distributed in two tubes, one containing the liquid polymer and the other the acceler-

Received for publication Nov. 4, 1955; revised by the authors Feb. 28, 1956.

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ators. Uniform setting depends upon thorough spatulation. The setting time is influenced by temperature, relative humidity, as well as the ratio of accelerator to liquid polymer.[2]

Since the elastic properties of these materials at the time of removal of the impression from the mouth determine the degree of reproducibility, it was decided to study the elastic properties during the setting period.

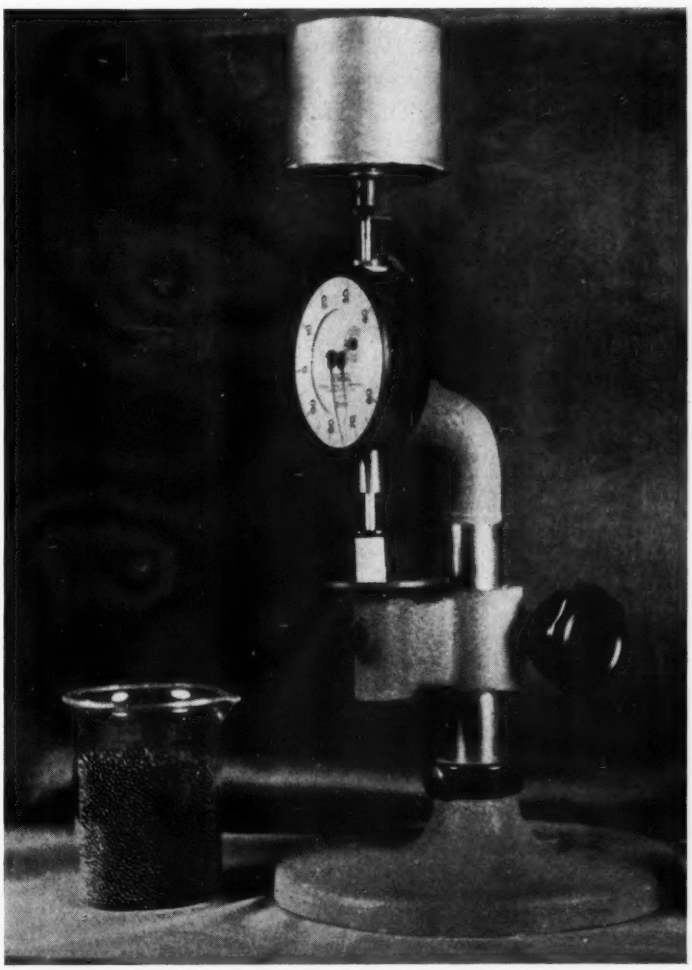

Fig. 1.—The instrument used for testing strain in compression, and permanent set.

METHODS AND MATERIALS

Two tests were used in this investigation to study the elastic properties. To determine the comparative strain in compression and permanent set, the test from the American Dental Association's Standard Specification No. 11 for Hydrocolloidal Impression Materials was chosen, the only variation introduced being the time of application of initial load.

For most materials tested, it was possible to remove the specimen from the mold and place it in the instrument shown in Fig. 1 early enough to permit application of an initial load calculated to produce a stress of 100 Gm./cm.^{2}, at five minutes from start of mix. A few materials were too plastic at this time so that the earliest application was six minutes. All materials were tested by application of the initial load at six, eight, and ten minutes, and for some materials also at seven and nine minutes. Thirty seconds after the time of application of the initial load, the dial indicator was read and the value so obtained is designated as A. Sixty seconds after applying the stress of 100 Gm./cm.^{2}, an additional load calculated to produce a total stress on the specimen of 1,000 Gm./cm.^{2} was gradually applied during an interval of ten seconds. Thirty seconds after the beginning of the application of the stress of 1,000 Gm./cm.^{2}, a reading, B, of the dial indicator was taken.

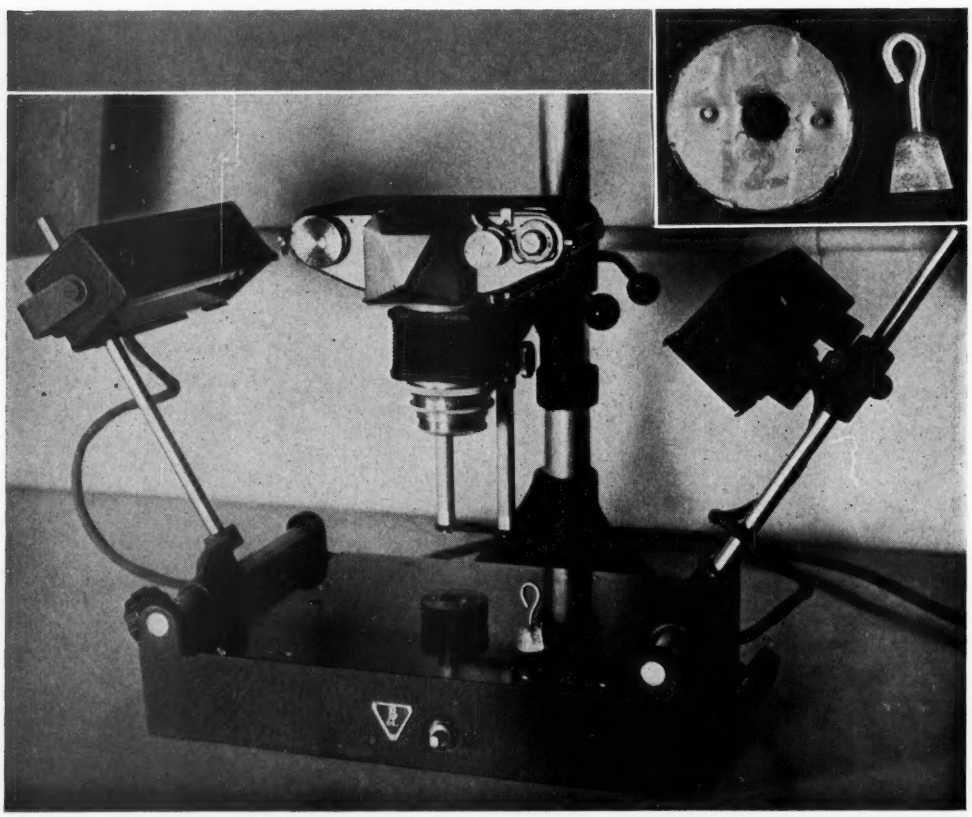

Fig. 2.—The camera, specimen tray with measuring pins, and the plastic cone plug for the determination of dimensional stability.

The difference between reading A and B divided by the original length of the specimen times 100 is designated as the percentage of strain between the stresses of 100 Gm./cm.^{2} and 1,000 Gm./cm.^{2} in Table II. Sixty seconds after beginning the application of the stress of 1,000 Gm./cm.^{2}, the specimen was released of all stress for a period of sixty seconds. Then a load calculated to produce a stress of 100 Gm./cm.^{2} was applied for thirty seconds, at which time a reading of the dial indicator

was taken. This reading was designated as reading C. The difference between readings A and C divided by the original length of the specimen, times 100, is listed as the permanent set in per cent in Table II.

The effect of variation in ratio of accelerator and polymer was determined for several materials using the test described above. For these tests the mixes were made using twice or one-half the amount of polymer as recommended by the manufacturer.

The second test used was designed to simulate the dental impression technique as closely as possible and, at the same time, yield numerical values for comparison. The specimen preparation for this test consisted of filling a small bakelite tray, containing mechanical locks, with the mixed impression material (Fig. 2). An acrylic resin plug (Fig. 2) of inverted cone shape with 14 degree taper was lubricated lightly and inserted into the center of the tray. Brass reference pins were inserted into the mix 5 mm. from opposite sides of the plug (Fig. 2).

The temperature of the tray and plug was held at 37° C. before the start of the mix, and after the tray was filled the impression material was cured at 37°C. At a definite time after the start of mix, an initial exposure was taken with a 35 mm. camera focused on the cross marks on the ends of the reference pins. Five seconds after exposure, the plug was removed and a second exposure was made at two and one-half minutes after the initial exposure. Subsequent photographic records were taken at fifteen, thirty, and sixty minutes in order to determine dimensional changes upon storage at room temperature. After development, the films were read using a micrometer microscope. The deformation upon removal was taken as the change (difference) in dimension between the initial exposure and the exposure after the removal of the plug, whereas deformation upon storage was taken as the change in dimension between the latter exposure and subsequent exposures.

TABLE I

NAME	MANUFACTURER	LOT	PURCHASE DATE
Coe-Flex	Coe Laboratories, Inc.	FF1	January 1955
		SS1	July 1955
Duraflex	Reliance Dental Mfg. Co.	None	January 1955
Sta-Tic	Stalite, Inc.	None	January 1955
Permlastic	Kerr Mfg. Co.	JJ628KK187	January 1955
		JJ631KK190	July 1955
		JJ292JJ275482	May 1954
Form-Flex	The William Getz Corp.	8001	January 1955
Paragel	Dental Perfection Co., Inc.	100	January 1955
Neo-Plex	Surgident, LTD	2155	January 1955

In order to help evaluate the setting characteristics of these materials, the time was recorded from start of the mix until the materials lost their tackiness to light finger pressure.

Seven rubber base impression materials were purchased on the open market and used in this investigation as listed in Table I.

In the data presented, code letters independent of the sequence used in Table I are used to designate the materials.

In an attempt to make a practical comparative test of the rubber base impression materials with the reversible and irreversible hydrocolloid impression materials, 130 stone models were constructed from a steel model using standard dental practices. A four-unit fixed bridge consisting of a three-quarter crown on a cuspid, two cast pontics, and a full crown on the first molar had previously been constructed to fit this steel model. The bridge was used as the standard for comparison of the stone models to the original steel model.

RESULTS

The data obtained from the two tests described above are listed in Tables II, III, and IV. All values reported are averages of tests on three specimens.

From the standard specification test for strain in compression (Table II) it was found that the various rubber base impression materials tested behaved differently.

For some materials (C and F) the strain decreased rapidly when the time of application of the load was changed from five to ten minutes.

For other materials (A, B, D, and E) less improvement in strain occurred, and one material (G) showed no improvement in strain.

Fig. 3 illustrates the type of curves obtained when percentage strain in compression, and permanent set is plotted as a function of time of initial loading for one of the materials of each type (materials F and G).

The standard specification for hydrocolloidal impression materials sets 4 per cent minimum and 20 per cent maximum limits for the deformation between 100 Gm./cm.^{2} and 1,000 Gm./cm.^{2} and a maximum limit of 3 per cent for permanent set.

TABLE II

TIME OF INITIAL LOAD	PER CENT STRAIN IN COMPRESSION							PER CENT PERMANENT SET						
	MATERIALS							MATERIALS						
	A	B	C	D	E	F	G	A	B	C	D	E	F	G
5		26	28	30		37	18		16	21	20		30	9
6	22	21	23	21	15	24	19	10	10	18	10	8	16	10
8	13	15	11	14	11	11	18	4	5	4	5	4	5	8
10	11	15	7	13	12	9	19	3	5	2	3	3	3	9

It can be seen from Table II that two of the seven materials do not comply with the standard specification for hydrocolloidal impression materials, even when tested ten minutes after the start of mixing. Five materials do comply with the requirements if tested ten minutes after the start of mix, whereas none have less than 3 per cent permanent set at an earlier time. Most materials have more than 20 per cent strain in compression at six minutes, and their permanent set at six minutes varies from 18 to 8 per cent. At eight minutes all materials tested showed strain in compression values between 4 and 20 per cent; the permanent set was 4 to 5 per cent except for material G, which had an 8 per cent permanent set.

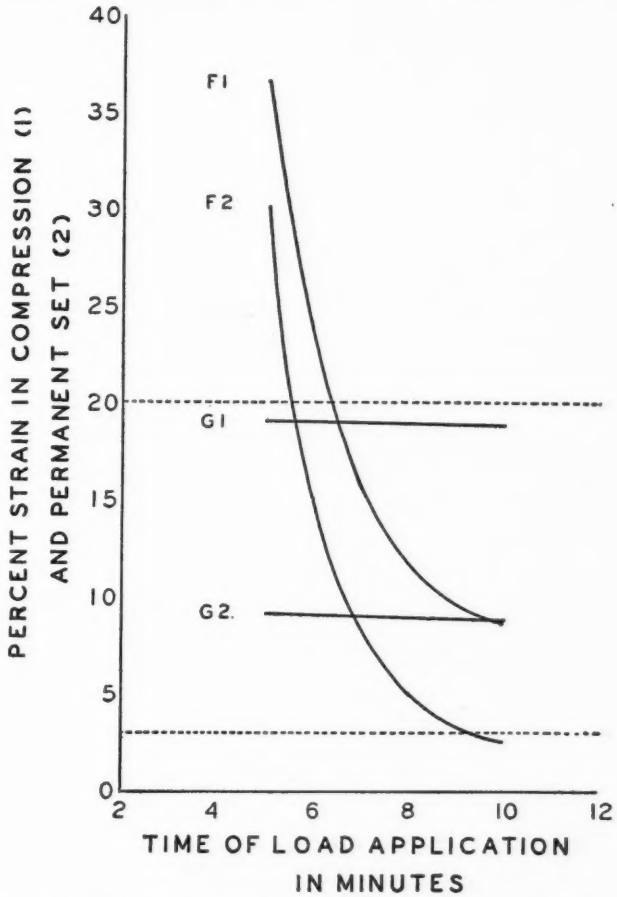

Fig. 3.—The per cent strain in compression and per cent permanent set as a function of time of load application.

At the time of setting as indicated by the manufacturer's directions (approximately six minutes from the start of mixing), none of the materials would comply with the specification requirements for permanent set.

The time of loss of tackiness for the different materials tested varied from two to five minutes from start of mix. No relation was found to exist between time of loss of tackiness and time of reaching permanent set values below 3 per cent.

Data for tests performed on specimens produced by variation of the polymer/accelerator ratio are listed in Table III. The variations introduced caused more strain in compression and more permanent set than when the manufacturer's recommendations were followed.

TABLE III

	STRAIN IN COMPRESSION			PERMANENT SET		
	POLYMER/ACC. RATIO			POLYMER/ACC. RATIO		
	MFG'S DIRECTIONS 1/1	2/1	1/2	MFG'S DIRECTIONS	2/1	1/2
Material C	7	11	12	2	4	2
Material F	11	14	17	5	8	7

The significance of compliance with the described test designed for hydrocolloidal impression materials will be discussed later in this paper.

In Table IV the results of the second test are listed. The values for change upon removal of the inverted cone plug of 14 degree taper at five minutes varied from .03 to .56 per cent and upon removal at ten minutes from .01 to .09 per cent.

During storage for thirty and sixty minutes, linear dimensional changes up to .47 per cent were measured for some materials, whereas others did not change upon storage. No further change in linear dimension was noted upon storage for twenty-four hours.

TABLE IV

	TIME OF REMOVAL (MINUTES)	MATERIALS						
		A	B	C	D	E	F	G
Change in % upon removal	5	.03	.11	.25	.07	.18	.56	.02
	6	−.13	.03	.22	.01	.06	.33	.01
	8	.05	−.02	.13	.01	.00	.06	.04
	10	.01	−.05	.09	.02	.04	.07	.01
Change upon 30 minute storage	5	.06	.15	.06	.11	.02	−.02	.15
	6	.23	.18	.10	.08	.08	.08	.21
	8	.04	.03	.08	.06	.00	.02	.27
	10	.02	.05	.07	.01	.02	.01	.04
Change upon 60 minute storage	5	.38	.17	.03	.09	.02	.12	.22
	6	.35	.07	.04	.08	.12	.06	.30
	8	.08	.10	.04	.06	.01	.10	.47
	10	.07	.06	.09	.04	.02	.00	.22

It was found that the later the inverted cone plug was removed, the smaller was the linear dimensional change upon removal, and, also, the smaller the changes upon storage indicating some of the storage changes to be a result of elastic memory.

It was found from the comparison of the stone models constructed from the rubber base and hydrocolloid impression materials that the fit of the bridge was determined not only by the impression material used, but also by impression technique; therefore, no conclusive evidence regarding fit of the bridge could be found for any one type or brand of impression material. It was noted in this comparison that all stone models made from rubber base impression material had a superior surface density to all other impression materials except one brand of reversible hydrocolloid. None of the irreversible hydrocolloids used with or without a fixing agent rendered as dense a surface on the stone models as did the rubber base impression materials.

The findings of this study are in agreement with the conclusions of Tylman,[3] Bailey,[4] Rosenstiel[5] and Pearson.[6]

DISCUSSION

It should be noted that the test for comparative strain in compression and permanent set used in this study was designed for evaluation of hydrocolloidal impression materials for specification purposes. It would, therefore, not be logical to evaluate a material of a different type entirely on the basis of this test without some modification.

In formulating a standard specification, the choice of experimental conditions for preparation of samples and of details such as load applied, length of load application, and maximum and minimum values are decided upon after careful consideration of the clinical and laboratory performance of several materials of the type in question, and numerical values and limits are chosen to provide a basis for rejection of inferior products, and for passing of products of satisfactory working characteristics.

The test under discussion does fulfill these requirements when used for hydrocolloidal impression materials, but the fact that most Thiokol impression materials do not comply with the requirement for permanent set does not necessarily imply that these materials are unsatisfactory as impression materials.

A considerable amount of clinical experience with various brands would be necessary in order to establish maximum and minimum limits for specification purposes. The test employed does indicate important differences in behavior of various brands of rubber base impression materials, and, also, it points out the importance of the degree of polymerization for the development of the elastic properties. In most instances, the setting time claimed by the manufacturer does not assure satisfactory elastic properties.

It should be noted that an exact definition of setting time has not been given by the manufacturers of these materials. Also, it should be realized that a definition of setting time should be based not only upon laboratory results but also upon careful clinical observations.

Subject to modifications from clinical experience, this report indicates that the setting time of rubber base impression materials should be determined as that time at which the optimal elastic properties are obtained when tested over a practical limit of time.

The practical limit of time in this study was considered to be up to ten minutes from the start of mixing. Some of these materials did not attain satisfactory elastic properties within this time limit.

The inverted cone test indicates that those materials which showed low values for strain in compression and permanent set give sufficient accuracy and stability in storage for dental impression purposes. This test also demonstrated the significance of the polymerization time.

In making stone models from impressions of the steel model the highest degree of accuracy was obtained when rubber base impression materials were used in a previously adapted tray of self-curing acrylic resin with 2 to 3 mm. thickness of the impression material. Bulky impressions, where the impression material extended into areas with heavy undercuts, consistently showed less accuracy (poor adaptation of the bridge). Similar results were found when reversible and irreversible hydrocolloids were used.

CONCLUSIONS

For most rubber base impression materials, the elastic properties improved considerably when they were allowed to set longer than recommended by the manufacturer.

After proper setting, most of these materials exhibited excellent elastic properties and stability during storage for at least twenty-four hours.

It would appear that a reduced setting time for most rubber base impression materials would be desirable for their use in dentistry.

Large deviations from the manufacturer's recommended ratio of the components is not advisable since inferior elastic properties will result.

The lack of tackiness is not a satisfactory indicator of setting time for these materials.

Best accuracy in reproduction particularly over long spans was obtained by a technique utilizing an individual tray of acrylic resin allowing 2 to 3 mm. thickness of the impression material, avoiding extension of the impression material into larger adjacent undercuts.

REFERENCES

1. "Thiokol" Liquid Polymer LP-2. Thiokol Corporation, Trenton 7, New Jersey.
2. Jorczak, F. S., and Fettes, E. M.: Polysulfide Liquid Polymers, Indust. & Engin. Chem. **43**:324-328, 1951.
3. Tylman, Stanley D.: Theory and Practice of Crown and Bridge Prosthesis, ed. 3, St. Louis, 1954, The C. V. Mosby Company, p. 505.
4. Bailey, L. R.: Acrylic Resin Tray for Rubber Base Impression Materials, J. Pros. Den. **5**:658-665, 1955.
5. Rosenstiel, E.: Rubber Base Elastic Impression Materials, Brit. D. J. **98**:392-394, 1955.
6. Pearson, S. L.: A New Elastic Impression Material, Brit. D. J. **99**:72-76, 1955.

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IMPRESSIONS AND SILVER-PLATED DIES FROM A RUBBER IMPRESSION MATERIAL

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AN IDEAL IMPRESSION IS one that can produce a cast so accurate that a complete fixed partial denture can be made on it. The cast should have removable metal-plated dies placed accurately in relationship to the adjacent teeth or edentulous region. Until the elastic rubber base materials became available, the reversible hydrocolloids came the closest to meeting the requirements for impressions and produced the best casts. The exacting requirements in the use of the hydrocolloids,[1,2] together with their shortcomings, kept them from becoming universally popular in crown and bridgework. The rubber impression material, if handled correctly, can be used to produce impressions, casts, and dies accurate enough to make a complete fixed partial denture without using supplementary impressions. The rubber impression material has been shown to be extremely accurate in exhaustive laboratory tests,[3] but attempts to electroplate these impressions with copper have failed. However, these rubber impressions can be electroplated successfully with silver.

COMPARISON OF IMPRESSION MATERIALS

The rubber impression material offers advantages over either hydrocolloid or modeling compound. The rubberlike material is much easier to handle at the chair than reversible hydrocolloid. It requires no boiling, tempering, or storing at critical temperatures. It requires no special equipment as does hydrocolloid. The elastic impression remains dimensionally accurate after it is formed so that there is not the urgency for immediate pouring of the casts that is essential with hydrocolloid impressions. The elastic rubberlike material will go exactly where it is carried by the band or tray, while the gingival tissues must be retracted when hydrocolloid is used, in order that the margins of the preparations can be recorded accurately in the impression. The rubber base material can be electroplated more easily than hydrocolloid. Plated dies are superior to stone dies for the construction of any fixed restoration.

Since the rubber impression material is elastic and is not permanently deformed when it is removed from undercuts, it will regain its shape without fracture. Modeling compound will distort or fracture when it is removed from undercuts. Distortion of a modeling compound impression is almost undetectable, and, if the impression material fractures, an indefinite finish line is formed on the die. The rubber impression material is mixed and used at room temperature so that there is no chance of injuring the pulp by heat, as can be done with modeling compound.

Received for publication Dec. 2, 1955; revised by the author Feb. 28, 1956.

Modeling compound impressions made in copper bands cannot produce the one cast upon which the restoration may be completed. This can be done with the rubber impression materials. The rubber impression material is carried to place by properly fitted copper bands. The copper bands carry the material subgingivally, and assure an accurate impression of all shoulders and finishing lines on the prepared teeth. The relationships of the individual teeth to each other are recorded by making the impressions within one acrylic-band tray. This cannot be done with modeling compound.

Fig. 1.

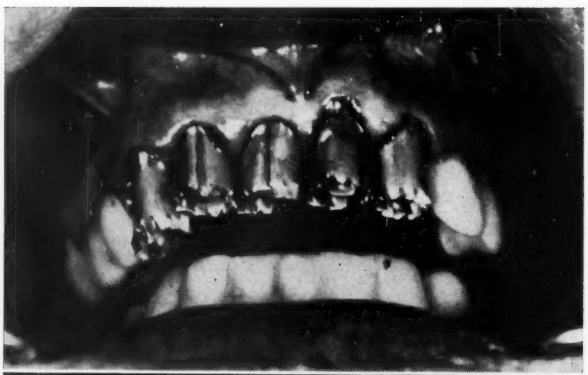

Fig. 2.

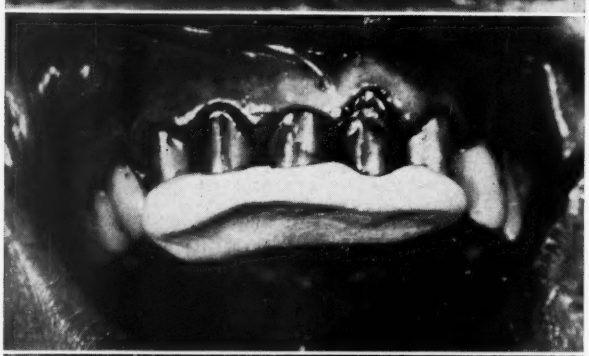

Fig. 3.

Fig. 1.—Copper bands are fitted to the prepared teeth. The occlusal ends of the bands are notched to retain the acrylic resin.

Fig. 2.—An autopolymerizing acrylic resin is used to lute the copper bands together.

Fig. 3.—The acrylic resin and copper band trays are prepared for making the rubber impressions of the prepared teeth.

THE ACRYLIC-COPPER BAND TRAY

Annealed copper bands are contoured and festooned to fit each of the prepared teeth. The length of each band is reduced until it extends 2 to 3 mm. beyond the occlusal surface of the prepared tooth. If the bands are not fairly secure on the

teeth, the gingival end can be crimped in for a tighter grip (Fig. 1). The occlusal end of the bands are notched to retain the acrylic resin which will attach them to each other.

Autopolymerizing acrylic resin is mixed in a dappen dish. When the resin has reached the "dough stage," it is placed over the occlusal ends of the copper bands and on the edentulous areas. The resin is allowed to harden in the mouth (Fig. 2).

The copper bands, which are held together in one piece by the resin, are removed. The acrylic resin that may have touched the tooth inside the bands is reamed out with a large round bur. The imprint of the preparation or tooth in the resin will indicate the contact of the acrylic resin with the tooth (Fig. 3).

THE IMPRESSION

Three parts of the white cream and one part of the brown cream (accelerator) of the rubber impression material are laid out on a large glass slab or paper pad. A heavy rigid spatula is used with short rapid strokes to mix the two ingredients together until a homogeneous smooth texture of the mix is attained. The color of the mix should be uniform and without white streaks. The mixing should be completed in 30 seconds. The time required for setting can be increased by using less of the brown (accelerator) cream.

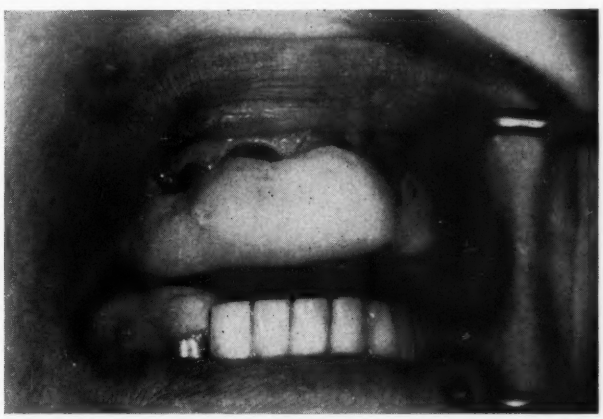

Fig. 4.—The acrylic resin and copper band trays are in position. Three separate trays are used in the upper arch. A complete arch rubber impression is made over these trays after the rubber impressions are made in them.

The material is mixed, as described above, and inserted in the acrylic-copper-band tray (in the copper bands and on the ridge areas). The material is worked around inside each band with a plastic instrument to release any trapped air. The filled acrylic-copper-band tray is placed in position over the teeth with enough pressure to firmly seat all of the copper bands. The tray is held lightly in position until the impression material has set. Do not remove this impression to inspect it (Fig. 4).

Due to the "elastic memory" of the material, it cannot be corrected by adding new material inside an impression. If the impression is unsatisfactory for any reason, it should be discarded and another one made.

A stock metal tray is fitted so that it will cover the acrylic-copper-band tray and the adjacent teeth. This is for the over-all impression that will be used to relate the dies to the adjacent teeth.

Larger quantities of the impression material are required for the over-all impression. Two parts of white cream are used with one part of brown cream for this impression. The setting time for the over-all impression is not critical, and

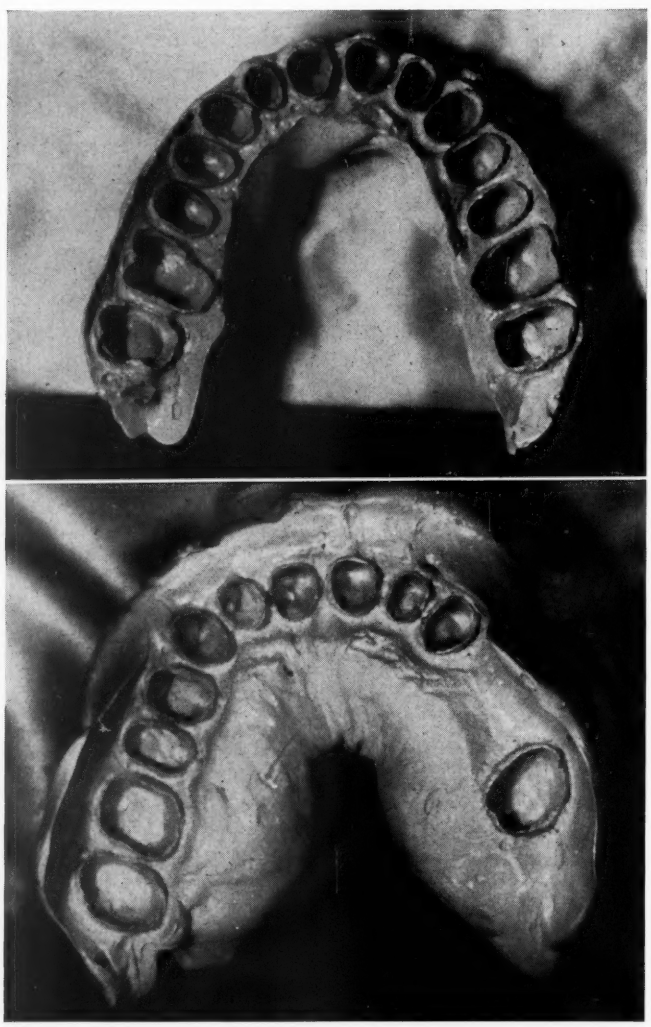

Fig. 5.—Two completed impressions.

the additional accelerator will hasten the set. The material is mixed in the same manner as before and placed in the tray. The large metal tray is inserted over the acrylic-copper-band tray (which has not been removed) and held in position until the impression material has set.

When the impression is removed, the acrylic-copper-band tray will be imbedded in the large over-all impression. The impression is carefully inspected to make

sure that all critical margins are sharp and clear. If, for any reason, the impression is unsatisfactory, the impression material is peeled out of the stock metal tray, and then out of the copper bands, and the entire procedure is repeated (Fig. 5).

SILVER-PLATED DIES AND MASTER CAST

If the impression is satisfactory, it is electroplated with silver. The following equipment and materials are necessary: (1) an electroplating machine regulated in milliamperes, (2) silver cyanide solution, (3) a pure silver anode, (4) pure

Fig. 6.

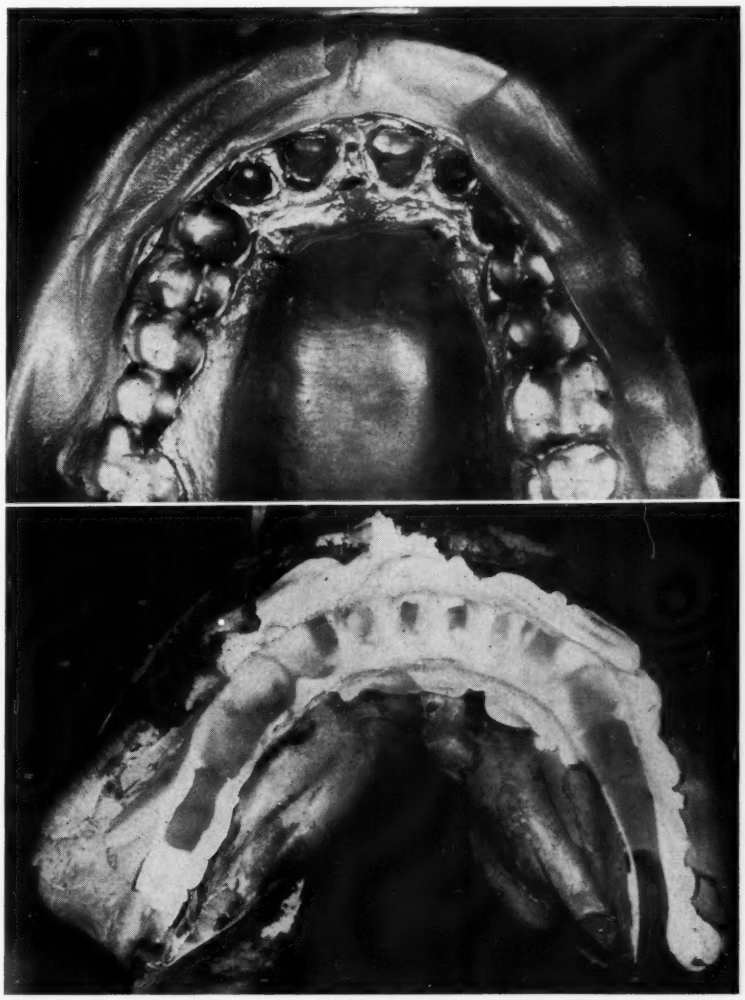

Fig. 7.

Fig. 6.—The rubber impression is metallized with pure silver in colloidal suspension (Staco 101).
Fig. 7.—The silver-plated impression before the precision stems and rods are added.

silver in colloidal suspension for use as the metallizer (Staco 101). There can be no material other than the rubber impression material in the plating tank. No plaster or modeling compound should be a part of the impression.

The impression is washed with a half-and-half mixture of 3 per cent peroxide and denatured alcohol to remove any debris or mucus, and dried. The metallizing agent is brushed on and into the areas to be plated (Fig. 6). A silver or copper wire, approximately 18 gauge, is attached to the impression tray and extended into a part of the impression. It is not necessary to extend the wire into the impression of the prepared teeth. Electrical conductivity is established between the wire and the metallized areas of the impression by painting-on "leads" with the metallizer. When the metallizer is dry (15 to 30 minutes), the impression is submerged in the silver cyanide solution and attached to the cathode outlet in the tank. The anode outlet holds the pure silver bar. The ammeter is set at 10 milliamperes per tooth to be plated, plus 10 milliamperes for the exposed leads.

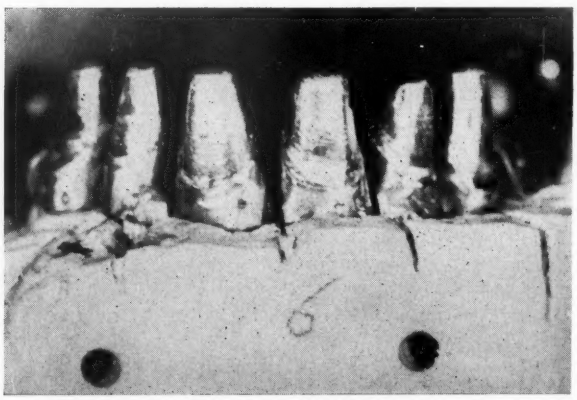

Fig. 8.—The removable silver-plated dies in the master cast.

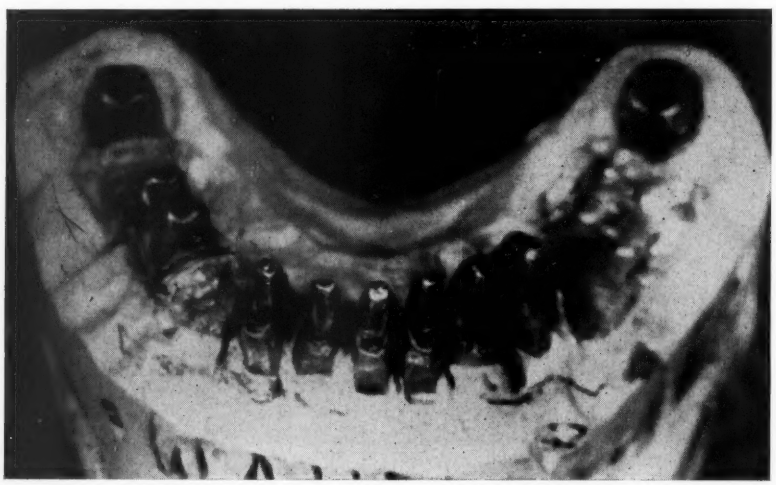

Fig. 9.—The removable silver-plated dies in a master cast.

A flash of silver should appear on the metallized surfaces in 15 minutes. The impression is removed from the tank and washed thoroughly with water to remove the cyanide solution. It is then dried with compressed air. All areas that do not require a buildup of plating are covered with molten wax. A minimum of six

hours of plating is necessary; however, overnight plating is best (Fig. 7). After a sufficient thickness of silver is built up, the impression is removed from the tank and rinsed in tap water.

Precision dowel pins with holes to accommodate the locking rods are positioned in each preparation, and aligned in relation with each other by means of these locking rods. A flux of 50 per cent hydrochloric acid and 50 per cent glycerin is brushed into each plated impression. When the dowel pins are in each preparation with the locking rods positioning them, low-fusing (Mellot's) metal is poured into each tooth, but only to the height of the gingival line. After the metal solidifies, the dowels are lubricated. Then the impression is boxed and poured in a hard stone. After recovering the cast from the impression, each die is separated with a thin coping saw or rotary saw blade, and made removable. This procedure is similar to that used in the reversible hydrocolloid technique (Figs. 8, 9). In this procedure, however, the locking rods must be withdrawn from the holes in the ends of the dowel pins before the dies can be removed. When the locking rods are replaced, the dies are locked firmly in an accurate and positive positional relationship to each other, and the restorations may be completed on this one master cast.

SUMMARY

A technique has been described for using a rubber base impression material for making a master cast with silver-plated removable dies. Certain advantages over reversible hydrocolloid and modeling compound impression materials have been noted. The one master cast with silver-plated removable dies for the complete fabrication of a dental restoration can be made without supplementary impressions obtained from the patient.

This technique was devised by Dr. A. B. Weinstein and his staff while Dr. Silver was a member of this staff.

REFERENCES

1. Sears, A. W.: Hydrocolloid Impression Technique for Inlays and Fixed Bridges, D. Digest **43**:230, 1937.
2. Thompson, M. J.: Standardized Indirect Technique for Reversible Hydrocolloid, J.A.D.A. **46**:1, 1953.
3. Skinner, E. W., and Cooper, E. N.: Desirable Properties and Use of Rubber Impression Materials, J.A.D.A. **51**:5, 1955.

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REPRODUCTION OF TOOTH ANATOMY AND POSITIONAL RELATIONSHIP IN FULL CAST OR VENEER CROWNS

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THIS TECHNIQUE WAS DEVISED to allow for an accurate reproduction of original or modified tooth anatomy and positional relationship in full cast or veneer crowns. It can be used for the precise reproduction of buccal or labial anatomy in veneer crowns. The tedious and time-consuming carving of wax patterns is eliminated. The procedure is automatic and accurate, and is accomplished in a short time. The technique can be used also to make crowns that fit abutment teeth of existing partial dentures with ease and accuracy. Corrections made on the teeth of study casts can be incorporated in the final restoration, and pontics can be reproduced or supplied.

THE METHOD

An alginate impression of the teeth to be reproduced is made. This can be made directly in the mouth or from the study cast. The study cast can be modified as required, including the replacement of missing teeth. Otherwise similar corrections can be more crudely effected by carving out the appropriate areas of alginate in the impression.

Quick-curing acrylic resin powder and liquid are placed in separate dappan dishes. An extremely fine acrylic resin powder is not suitable for this technique, as it is difficult to apply uniformly. A small brush is first dipped into the liquid, and then a liberal amount of acrylic resin powder is picked up with the moistened brush. After drying the alginate impression with a blast of air, the acrylic resin is painted into the required areas so that a uniform layer is produced (Fig. 1). The acrylic resin should resemble an eggshell when it is fully set. The impression is tilted so that gravity will help to control the painting-in of the acrylic resin. The proper consistency of powder and liquid on the brush, and the occasional use of a gentle blast of air will aid in the uniform application of the acrylic resin and prevent the building up of thick areas. Although thick areas can be corrected by grinding internally, they cause excessive shrinkage externally, and should be avoided.

The acrylic resin shells thus produced are true reproductions of the surfaces involved, and can be used in a variety of ways to form the final patterns, which are invested and cast in the usual manner. A duplicate set of shells are lined with acrylic resin and used as temporary protection for the prepared teeth.[1] A third set of shells can be lined with resin on strategic teeth and kept as a record of the

Received for publication Oct. 5, 1955.

original occlusal vertical dimension. This allows all of the teeth to be prepared, and yet the original situation can be restored in a moment by inserting the resin replacements. As many acrylic resin shells as necessary can be made in a single alginate impression.

RESTORATION OF ABUTMENT TEETH

The acrylic resin shells (Fig. 1) are used in the construction of full crowns with resin veneers for the restoration of the cuspid abutments. The shells are removed from the alginate impression and the excess is trimmed away. Then they are filled with inlay wax and seated over the prepared abutment teeth, and the partial denture is inserted as a guide for positioning the shells (Fig. 2). This procedure can be accomplished more accurately by preparing one abutment tooth

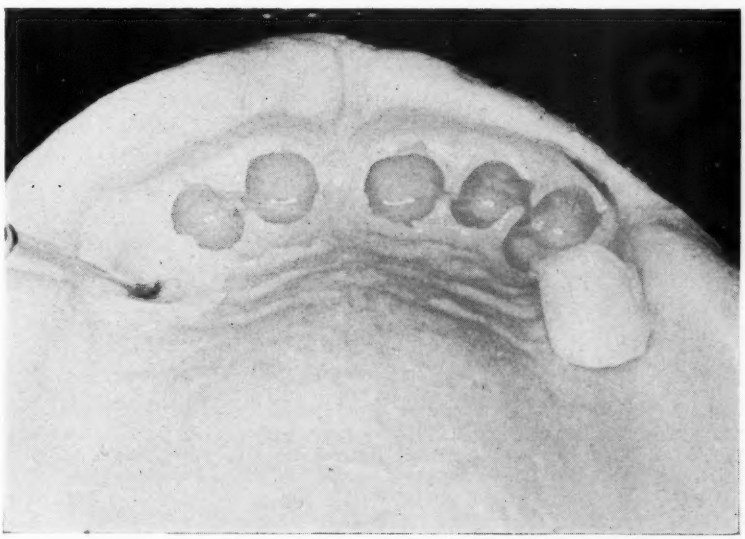
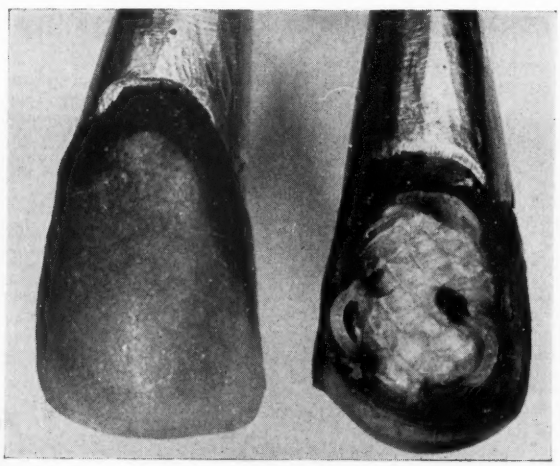


Fig. 1.—Acrylic resin is painted into an alginate impression to form shells which reproduce the contours of the teeth to be restored.

Fig. 2.—The acrylic resin shell is filled with inlay wax and placed on the prepared tooth, and the partial denture is placed in position to orient the shell to the tooth and the clasp.

and restoring it before the second one is prepared and restored. Copper band impressions of the abutment teeth are made, and the wax-lined shells are seated on copper-plated dies in order to correct the gingival margins (Fig. 3,*A*). The inlay wax in the acrylic resin shells allows for the proper seating of the patterns on the dies. The labial surface of the acrylic resin shell is removed with a separating disc and laid aside for use in the final labial wax-up. A plaster matrix of the labial surface may be made before the window is prepared and used as an alternate procedure. After casting, the acrylic resin veneer is processed, and the crowns are ready for seating (Fig. 4).



A. *B.*

Fig. 3.—*A*, The acrylic resin shell filled with inlay wax is in position on the die. *B*, The labial surface of the shell has been removed and retention provided for an acrylic resin facing to be added after the crown has been cast.

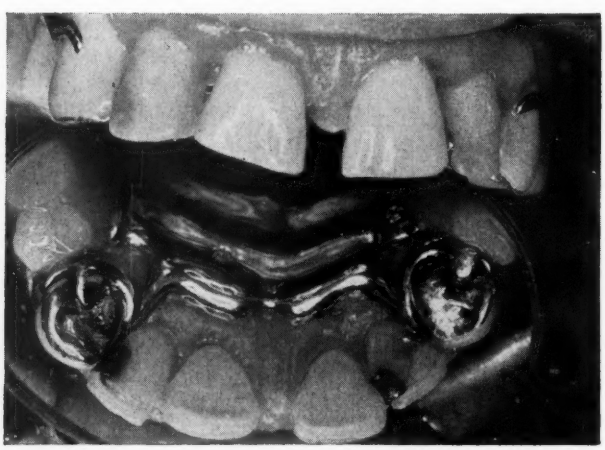


Fig. 4.—The completed restorations of both abutment teeth are in position. Note that the adaptation of the clasps to the abutment restorations has been maintained.

UPPER FIXED PARTIAL DENTURE

An original study cast of a proposed upper fixed partial denture is made, and the abutment teeth on a duplicate cast are modified as required (Fig. 5). Acrylic resin shells are formed in an alginate impression. Two sets of shells are made,

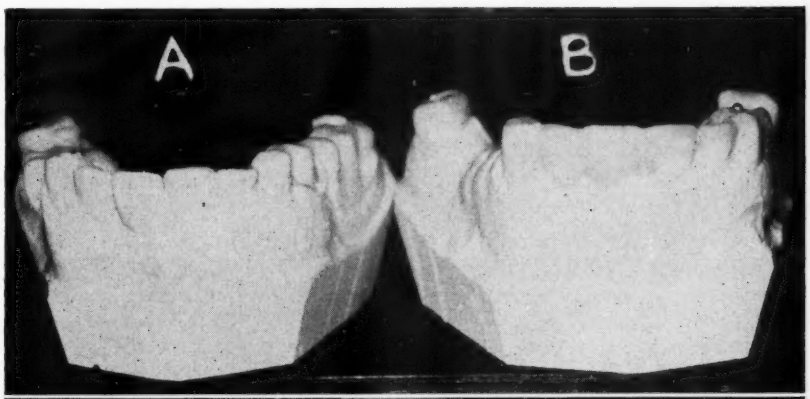


Fig. 5.

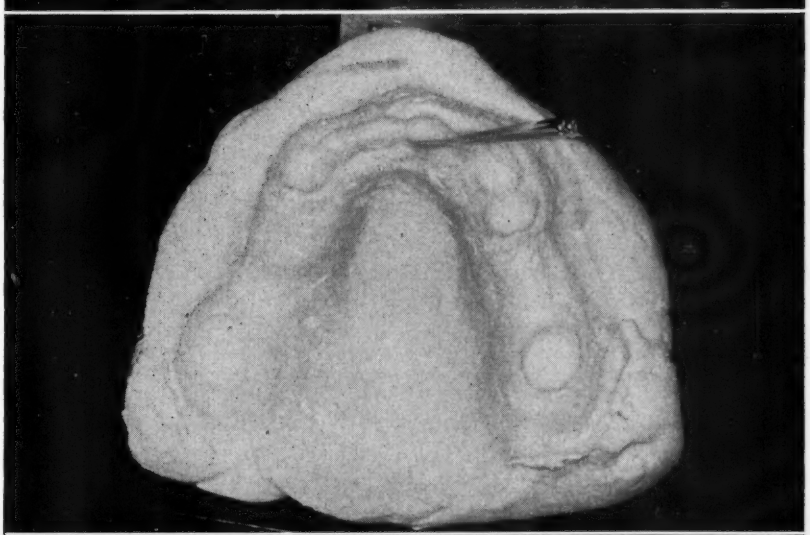


Fig 6.

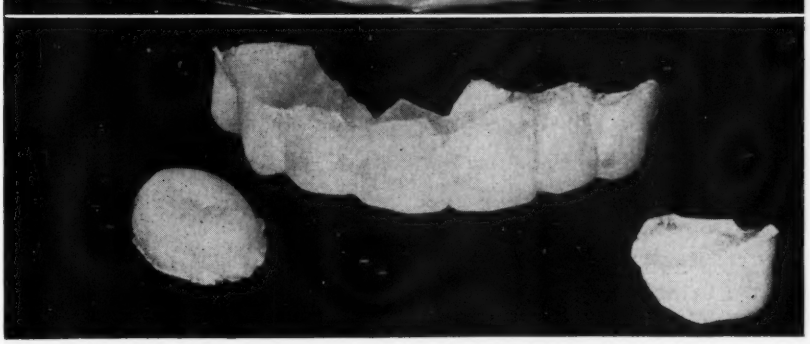
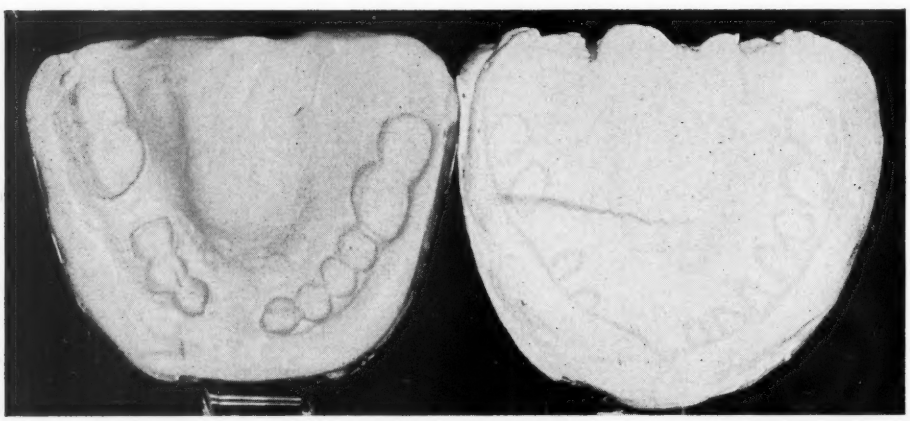


Fig. 7.

Fig. 5.—*A*, The original study cast. *B*, A duplicate cast of the modified abutment teeth.
Fig. 6.—Two sets of acrylic resin shells are made in an alginate impression.
Fig. 7.—The shells are removed from the impression.

one is used for the crown patterns, and the other, after lining with acrylic resin, is placed over the prepared abutments as temporary protection for the teeth (Fig. 6). The shells are removed from the impression and stored in water until they are used in order to prevent excessive shrinkage (Fig. 7).

A master cast to be used for the construction of individual patterns, but not for final assembly, is made. A wax impression of a study cast is made before the teeth are prepared and lined with a zinc oxide eugenol impression paste after all of the abutment teeth have been prepared (Fig. 8). The dies can be seated into this paste impression with ease. Whenever there is doubt regarding complete seating of the dies, the tip of each die is touched to an ink pad, and the transfer of the ink mark to the base of the impression confirms the proper seating when it is achieved.



A. *B.*

Fig. 8.—*A*, A wax impression of a study cast. *B*, The wax impression is lined with a zinc oxide and eugenol paste after the teeth are prepared in order to position the dies.

The original occlusal vertical dimension is retained, even though the teeth have all been prepared, by constructing a third set of acrylic resin shells for strategically located teeth, e.g., cuspids and molars. These shells are lined with acrylic resin and adjusted occlusally while other unprepared teeth are present to act as stops. When the last abutment is prepared, the previously adjusted lined shells are used as stops. These acrylic resin records of the vertical height of the teeth are stored in water. Their use in the mouth as temporary crowns would subject them to wear, or possible breakage or loss. They are used subsequently as stops in making interocclusal records and in fitting the abutment crowns.

The dies are lubricated, and thin wax is used to form wax copings. The acrylic resin shells are separated from each other with a separating disc, and each shell is seated over its wax coping and waxed to position (Fig. 9). Where acrylic resin veneers are to be made, the labial or buccal windows are removed with a separating disc, leaving the wax copings intact. The patterns are then completed.

When missing teeth have been replaced on the master cast, reproductions of these teeth can be made in the same manner as for natural teeth. The shells made from the restored teeth are filled with inlay wax and carved to form the pontic framework. This will assure the proper alignment, size, and shape of the completed pontics.

The patterns are invested and cast. A slightly longer burnout at high heat and accessory blind sprues are necessary to assure dense castings, but otherwise the procedure is the same as for wax patterns.

The framework is assembled on a master cast that was made from a plaster impression of all of the abutment crowns in position in the mouth. A labial shell of acrylic resin that was made in the alginate impression of the corrected study cast is used to provide exact labial contours (Fig. 10). This can be extended to include all of the buccal and labial surfaces. The shell is waxed into place in its proper position. After flasking, the shell is removed, and the correct form for the processing of the acrylic resin veneers remains.

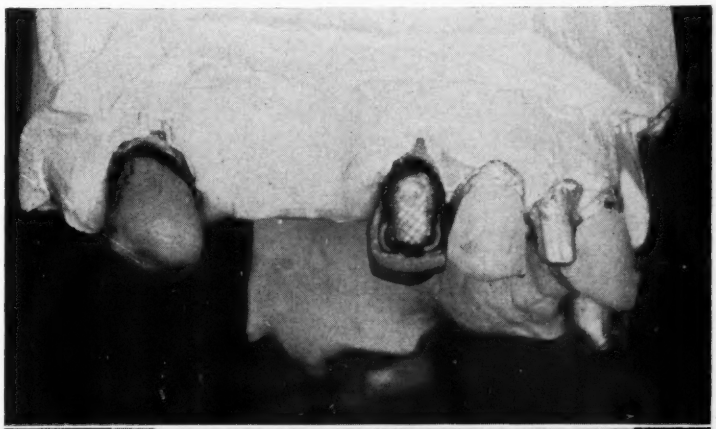


Fig. 9.

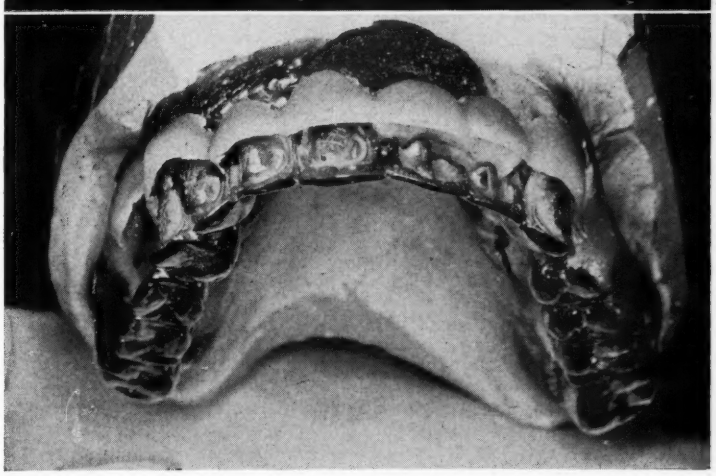


Fig. 10.

Fig. 9.—The crowns are in various stages of construction. The acrylic resin shells are used to determine the external shape of the restorations.

Fig. 10.—The assembled metal framework and the acrylic resin shell facing which is used to determine the contours of the labial and buccal surfaces of the veneers.

TECHNIQUE FOR PRECISION ATTACHMENT ABUTMENTS

The resin shell technique can be used for positioning precision attachments. The acrylic resin shell and pattern is made as previously described for a clasp abutment, and space is provided in it for the female part of the attachment. The crown is then cast and fitted. A small amount of acrylic resin is used to secure the female part of the attachment to the crown, which is then invested for soldering.

Large amounts of acrylic resin applied hastily will cause excessive contraction and inaccuracy of fit.

The female part of the attachment can also be secured to the acrylic resin pattern itself as shown in Fig. 11. In this procedure, the crown is cast directly to the female part of the attachment. This method introduces the possibility of error in the seating of the pattern on the die. While this is easily adjusted for a clasp denture, this error might not be tolerated with a precision attachment denture. Rechecking the pattern in the mouth after correction on the die is advisable.

Fig. 11.

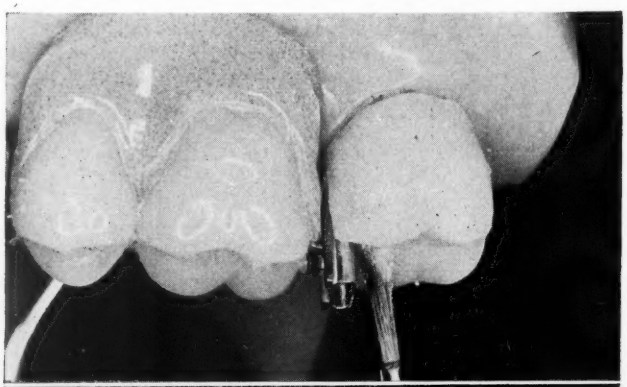


Fig. 12.

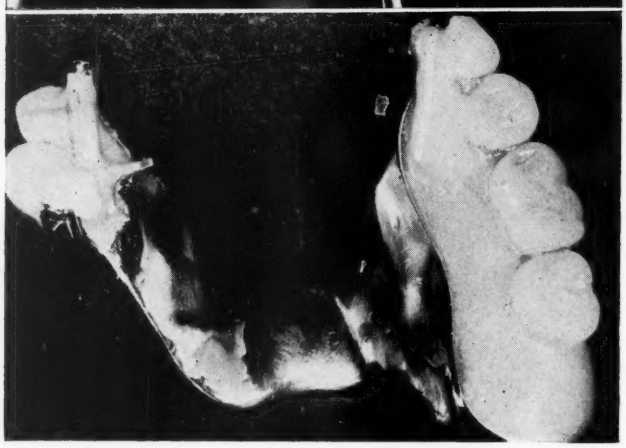


Fig. 11.—The female portion of a precision attachment is positioned in an acrylic resin shell by means of acrylic resin.

Fig. 12.—The male portion of a precision attachment is attached to a denture to align it for soldering.

Quick-curing acrylic resin can be used in repairing a precision attachment denture to attach a new male part to the denture, preparatory to soldering (Fig. 12). By this procedure, the alignment can be checked in the mouth before the actual repair is made. It will avoid the possible shifting that might occur under a plaster matrix, and which would not be noticed until after the repair was made. Small amounts of the resin should be painted on slowly in order to prevent excessive contraction of the acrylic resin. An alginate impression of the denture in the mouth is made after the new attachments have been secured with acrylic resin

(Fig. 13). Then a cast and plaster matrices are made to permit the removal of the teeth during the soldering operation and for their replacement later (Fig. 14).

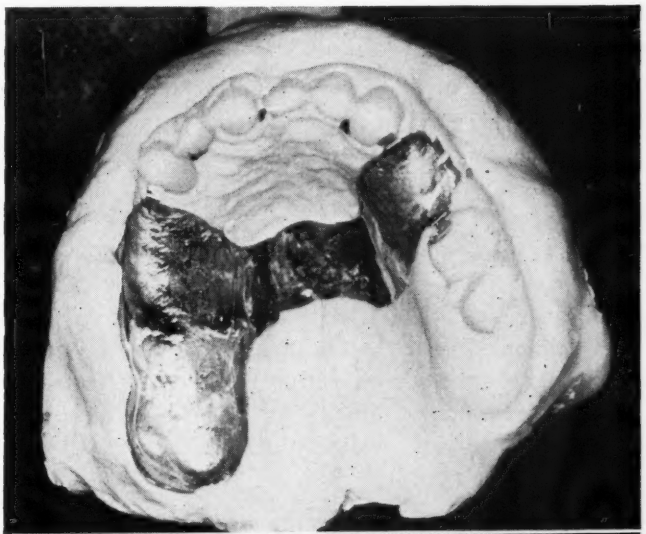


Fig. 13.

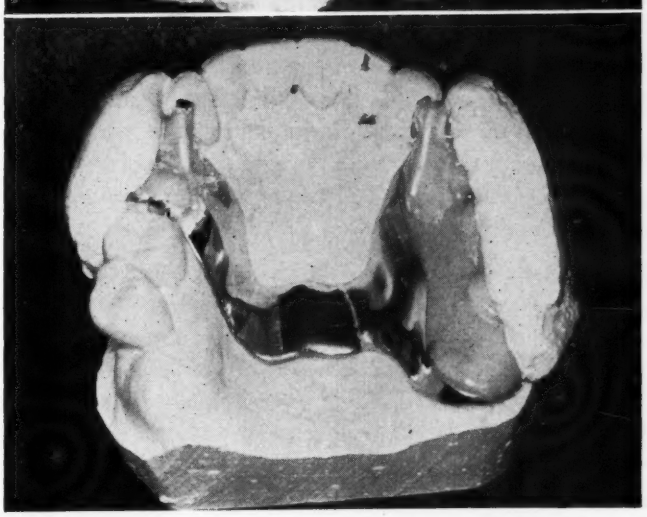


Fig. 14.

Fig. 13.—An alginate impression of the denture in place is made to produce a master cast with the parts in proper alignment.

Fig. 14.—Plaster matrices are made so the teeth can be removed for the soldering operations.

SUMMARY

Techniques which make use of quick-curing acrylic resins for making and repairing dental restorations are described. The materials are readily available and, if they are used properly, they will increase the accuracy of these restorations.

REFERENCE

1. Leff, Alexander: An Improved Temporary Acrylic Fixed Bridge, J. Pros. Den. **3**:245-249, 1953.

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IMPRESSION AND PATTERN TECHNIQUE FOR ANTERIOR THREE-QUARTER CROWNS

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IF A PERFECT WAX PATTERN for an anterior three-quarter crown preparation could be obtained easily by the direct method, objections to the increase in chair time would be of little consequence. However, perfect gingival adaptation and perfect proximal contour are difficult to produce by the direct technique because of limited access, restricted visibility, temperature variables, and the necessity of stabilizing the wax mass.

Many methods for obtaining an accurate impression and die of anterior three-quarter crown preparations have been developed. When a relatively rigid impression material such as inlay wax or impression compound is used as the impression medium, there is the problem of removing the impression from the tooth without distortion, because of the drag of the impression material over the height of contour of the tooth (in relation to the line of draw, which is usually in a lingual as well as an incisal direction). Undercuts almost always occur at the labiogingival areas of an anterior tooth.

The various elastic impression materials have been utilized for obtaining impressions of this type of preparation to avoid the problem of distortion. When a good impression of the gingival area is readily obtainable (this is a problem with nonpressure materials), the more accurate of these materials permit a satisfactory result. There are other disadvantageous factors which must be controlled with the elastic type of material, but a discussion of them is another subject.

When one of the relatively rigid impression materials such as inlay wax is to be used, the procedure described here is an excellent method for obtaining an impression of an anterior three-quarter crown preparation and fabricating a pattern from it. It embodies some of the principles of both the direct and indirect procedures. Wax patterns made by this method will produce castings that exhibit accurate gingival margins and no distortion at the labial and labiogingival margins.

It should be pointed out that the results are excellent only if each step of the technique is followed precisely.

The technique described here and used by a number of study clubs in the Pacific Northwest, was developed and taught by the late Dr. C. T. Fleetwood, Seattle, Wash.

Received for publication April 12, 1956.

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ARMAMENTARIUM

Instruments.—

Crown scissors, curved
Cotton pliers
Wax spatula
Wax carver (e.g., Hollenback No. 3)
Knife-edged mounted carborundum stone
Gold knife
Explorer, right angle
Rubber bowl
Inlay brush
Vibrator

Materials.—

Copper bands, 36 gauge, ½ inch long
Microfilm
Inlay wax
Staple
Dental tape
Coe Universal Investment
Cristobalite Investment

PROCEDURE

Select a copper band that stands out 0.5 mm. from the labial and prepared surfaces of the tooth at the gingival level. Anneal it by heating to red heat, then quenching in alcohol. Trim away the labiogingival portion of the band in the area gingival to the height of contour. Festoon the lingual and proximal surfaces of the gingival end of the band, and smooth the cut edges (Fig. 1).

In cases where the labial extensions of the preparation are greatly restricted to minimize the display of gold, thin the band slightly in the areas of contact of approximating teeth with a disc or stone. Lubricate the inside of the band and the prepared tooth.

Fill the band with softened inlay wax and allow it to cool without assistance. Reheat the wax in a definite manner as follows: Heat the pointed end and shank of a No. 7 wax spatula in the Bunsen flame, and force it into the band from the gingival end so that the point of the instrument goes down the labial surface of the band, and the shank of the heated spatula rests on the linguogingival edge of the band (Fig. 2).

This method of heating the wax within the band permits a plunger effect by the cool bulk of wax backing up the softer wax which takes the impression of the preparation. It also helps to center the tooth in the impression so that the band is not forced against the tooth; consequently, all of the margins of the preparation are registered in wax.

Allow the wax to cool until the glaze disappears. Then carry the band approximately halfway to place on the preparation. At this time, close the end of the band with the thumb, being sure to keep the band centered over the tooth. Seat it completely and hold it with positive pressure. Introduce a thin-bladed wax carver into the proximogingival areas from the lingual surface to make sure that the wax is well adapted at the gingival and labiogingival margins. Hold the band and wax steady for two minutes.

Then, still supporting the band from the incisal end, cut through its labial surface with a knife-edged stone. Rotate the stone from the incisal toward the gingival end (Fig. 3). If the band is very close to the labial surface of the tooth, do not cut completely through it, but while still stabilizing it from the incisal end, insert a gold knife at the labioincisal end and finish the cut toward the gingival

end (Fig. 4). The fact that the labial portion of the gingival end of the band has been trimmed is an aid in avoiding cutting the gingival tissue. When making this cut, be careful not to mar the labial surface of the tooth. While holding the wax in place from the incisal end, peel the two labial ends of the band proximally and remove the band carefully in a linguoincisal direction.

Carve the wax accurately and completely to the portion of the mesial and distal margins which is gingival to the height of contour (considering the line of withdrawal of the impression), but leave approximately 1 mm. of thickness of wax over the remainder of the labial margins. This will facilitate a later step in completing the carving of the wax pattern. Do *not* reduce the lingual or incisal bulk of wax (Figs. 5 and 6).

Fig. 1.

Fig. 2.

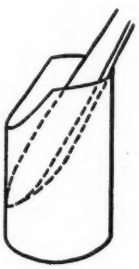

Fig. 3.

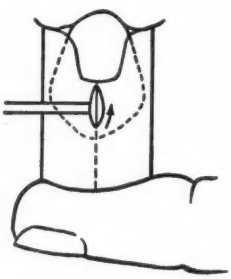

Fig. 4.

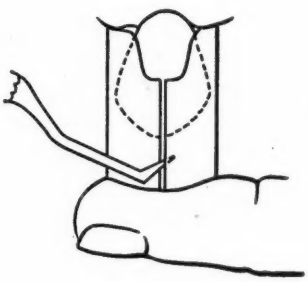

Fig. 5.

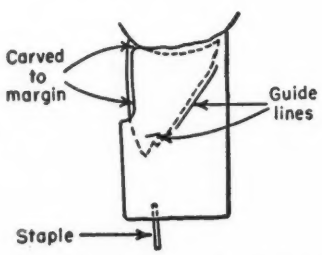

Fig. 6.

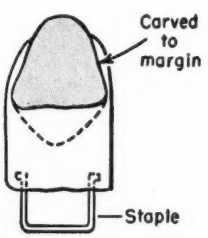

Fig. 1.—A copper band, trimmed and festooned preparatory to making the impression.

Fig. 2.—The wax in the band is heated in the labial and gingival areas with a wax spatula prior to being carried to the tooth.

Fig. 3.—The band is cut on the labial surface with a knife-edged stone.

Fig. 4.—The cut is completed with a gold knife; the band and wax are still stabilized by the finger.

Fig. 5.—The wax is carved to the margins only in the areas gingival to the height of contour. Guide lines, indicating the level of the incisal edge, and the lingual marginal ridges of the adjacent teeth are scribed into the wax.

Fig. 6.—A wire staple is inserted into the bulk of wax.

Scribe lines on the mesial and distal surfaces of the wax to indicate the lingual marginal ridge and incisal edge levels of the approximating teeth (Fig. 5).

Fashion a staple from a paper staple, with short projections at right angles to the legs of the staple (Fig. 6). Make sure the legs are close enough together to fit into the wax in a mesiodistal direction.

Holding the staple in a pair of cotton pliers, warm the ends of it in a flame and place them into the bulk of the wax immediately over and in a direction parallel with the proximal grooves of the preparation (Fig. 5). Cool the staple with a continuous stream of air applied from a distance of 10 to 12 inches, shortening this distance once the glaze has left the wax around the ends of the staple. Release the cotton pliers.

Loop a piece of dental tape (not floss) or an amalgam strip through the staple and, taking a short grip on the ends of the loop, carefully remove the wax in a direction parallel with the grooves of the preparation. Examine the interior of the impression for defects.

THE DIE OR CAST

The die for the crown in this technique is made of casting investment, and it is not removed from the pattern when the pattern is invested and cast.

Fig. 7.

Fig. 8.

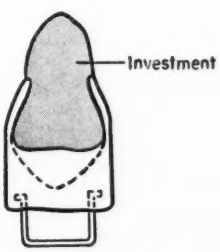

Fig. 9.

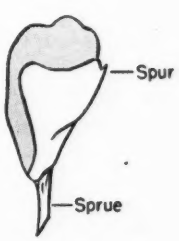

Fig. 7.—The casting investment is vibrated into the wax impression.
Fig. 8.—The wax impression and refractory die or cast.
Fig. 9.—The pattern is carved from the wax impression while it is in position on the refractory cast.

If the impression is acceptable, wash off any debris and the lubricant with soap and water and an inlay brush. The application of a mixture of 5 drops of hydrogen peroxide and 1 drop of 18 per cent ammonia will remove blood and lubricant.

Mix together on a piece of paper approximately 2 c.c. Coe Universal Investment (for adequate hardness) and 1 c.c. Cristobalite Investment (for expansion). Add this mixture slowly to 5 or 6 drops of water in a small rubber bowl. Spatulate the mix until it becomes quite thick but is still workable.

Dilute a drop or so of the mix in the palm of the hand until a milky consistency is reached. Use the point of an inlay brush to work the thin mix into all parts of the impression. Blow the excess investment out of the impression and off the margins to insure that no air bubbles are trapped on the cavity surface or on any margin.

Holding the impression by the dental tape (fingers gripping the staple), flow the heavy investment mixture into the impression. Use the motion of a vibrator to agitate the hand holding the inlay brush (Fig. 7). Fill the impression up to, but not over, the edges of the wax. Build up a small mound of investment in what would be the root portion. Dust a little of the dry investment on to the surface of the investment to absorb surface moisture and increase the hardness of the die. Lay it aside to set (Fig. 8).

When the investment has set, brush any loose powder off the wax and trim the die. Remove the staple, shape the pattern, and carve it to the margins. Use the marginal ridge and incisal edge guides, and the contact and contour marks to establish the desired thickness and contour of the pattern (Fig. 9). If the wax is carved too thin, the color of the investment will show through the wax; more wax for contour can be added. Add a projecting spur of wax near the gingival margin of the pattern; it will provide a safe means of engaging the casting when removing it from the tooth, and will be a positioning index in an impression, if the casting is being used as a retainer for a fixed partial denture. Wash the pattern and cast free of debris. Sprue and invest the pattern in the usual manner. It is important to make sure that the investment die is not dry or greasy when the pattern is invested.

There are some indications for an indirect-direct procedure. In these cases the die or cast is poured in die stone. Separate the wax and stone before doing any carving, first submerging them in warm water. Trim the die in the gingival areas, and lubricate it thoroughly. Place the wax impression back on the die, and carve it to the desired or approximate shape. It is then carried to the preparation in the mouth for the final carving and checking. A pattern obtained in this way is invested in the customary manner.

REFERENCE

1. Fleetwood, C. T.: Patterns for Cast Restorations by the Indirect Method, D. Digest **46**:57-62, 1940.

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BROADER CONCEPTS OF GOLD FOIL

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IT IS GRATIFYING to realize that the two simplest forms of gold foil operations performed today are those which render the most satisfaction to both the patient and the operator in respect to durability and service. They offer paramount indications for gold foil.

CLASS I

The Class I gold foil restoration may be fabricated in three different ways, all successful and all terminating in a finished restoration of high excellence. The selection of the method used depends primarily upon the ability of the operator. The basic preparation will greatly determine the ease with which the foil may be inserted, condensed, and finished. Contrary to the general practice of using inverted cone burs on the occlusal surfaces, these areas should be opened with short burs of the 700 series. This will produce a cavity which is essentially divergent in character. A slight divergency is to be desired in the isthmus portions of the cavity as well as at the mesial and distal walls where it adds support to the stress-bearing marginal ridges.

There are slight undercuts or retentive areas on the mesial and distal but only at the expense of the buccal and lingual walls (Fig. 1). These areas assist in starting and stabilizing the foil during condensation; the occlusal grooves are run out only to the extent of the enamel defects where they may terminate in (1) a sharp line angle (the easiest to prepare and fill) or (2) a square box (the best for terminating in deep, heavily rounded grooves), or (3) a small rounded semicircle (finished with a plain fissure bur). All groove extensions should lie in a slightly divergent plane to the pulpal floor to allow easy and accurate entry of the foil and condensers.

The simplest method of foil placement, though the most tedious, is often the wisest for the relatively inexperienced operator (Fig. 2). It is based on the use of cohesive foil throughout the entire operation. The gold is built to form in a concave manner. The first pellets are placed in the most distal areas and the mesial part is filled last.

The second method (Fig. 3) is usually the one of choice for the average operator. It is much faster, both in filling the cavity and in finishing, and has the added advantage of sealing the cavity walls more readily. The periphery of the cavity is lined with cylinders of noncohesive foil, which are wedged in place with large parallelogram hand condensers.

Next, large 1/16th pellets of cohesive gold (1/16th of a 4 grain sheet) are condensed with hand pressure along the pulpal floor, thereby wedging the non-

Read before the Academy of Restorative Dentistry, Chicago, Ill., Feb. 6, 1955.
Received for publication Dec. 14, 1955.

cohesive cylinders tightly into position. Additional cohesive pellets of 1/32nd size follow in the normal fashion, starting in the distal and building in a concave manner. When the margin areas are reached, the noncohesive gold is pinched off and the cohesive gold is built up to the margins.

The largest condenser point used should never be over 0.5 mm. in diameter to insure adequate condensation of the cohesive gold.

Fig. 1. Fig. 2.

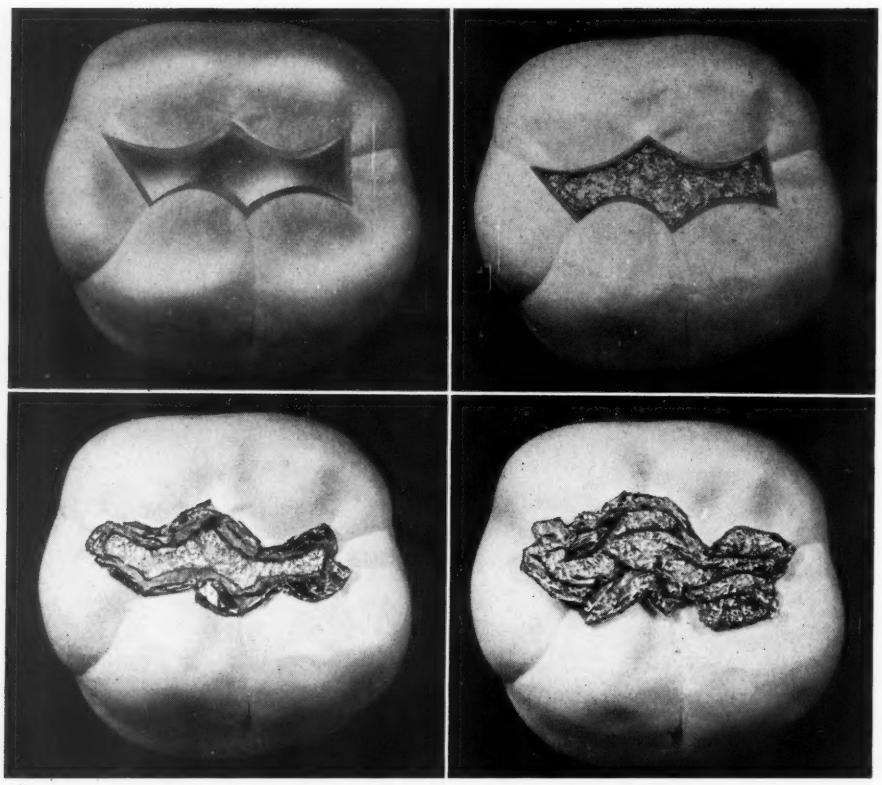

Fig. 3. Fig. 4.

Fig. 1.—A Class I cavity showing internal detail and symmetrical outline form.
Fig. 2.—All cohesive gold technique.
Fig. 3.—Combination noncohesive and cohesive gold technique.
Fig. 4.—All noncohesive gold technique.

The third method, and by far the fastest, should only be used by men of sufficient experience. As in the second method, the cavity is lined with noncohesive cylinders, each cylinder protruding from the cavity about one-third of its length, as shown in Fig. 4. Subsequent cylinders are wedged into place laterally until no further space exists. At this time, a wedge-shaped instrument is used to open an area in the center of the restoration, and an additional densely rolled cylinder is forced into position. Now condensation from an occlusal direction begins. First the operator uses hand condensation and large condensers, finally working down to the 0.5 mm. condensers, at which point a great deal of contouring

and finishing of the excess gold near the margins may be done. The final finish in this restoration is gained by burnishing. The operation may give a beautiful result but is not indicated in areas of excessive wear as soft foil will not stand strains as well as the cohesive foil.

All Class I preparations should be outlined and designed with a high regard for tooth conservation. The possible Class II operations which may follow must not be jeopardized or influenced by careless cutting. Therefore (Fig. 5), the typical occlusal outline must be patterned after the normal Class II occlusal dovetail form. This insures all teeth, but particularly such teeth as the lower first bicuspid where tolerances are very close.

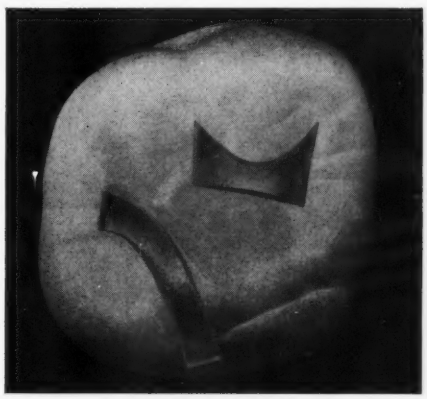

Fig. 5.—A Class I cavity in molars and bicuspids should conform to the normal Class II occlusal outline.

CLASS V

The classic outline form of the modern Class V foil is that conceived by W. I. Ferrier. This form was carefully analyzed and the variations from type have been classified.[1]

The three principal types are (Fig. 6):

1. The normal form is trapezoidal, and extended so that the mesial, distal, and gingival walls are covered by normal gingival tissue.
2. On anterior teeth the incisal wall is modified to a graceful curve blending with the curve of the gingival tissue. This reduces the possible display of gold, and blends harmoniously with the dental tissues and the labial plate of enamel.
3. In cases of an extension of decalcification into the interproximal embrasure, particularly in the lower bicuspid areas, a boxed extension may be indicated to secure greater protection.

The important principle of keeping all occlusal walls parallel in a series of posterior restorations is illustrated in Figs. 7 and 8. These walls are established parallel to the occlusal plane of the mouth regardless of the inclinations of the various individual teeth.

The position of the occlusal wall under normal conditions should be slightly toward the occlusal from the buccal height of contour to prevent the possibility of food debris accumulating near the margin. In a very clean mouth or a mouth with caries occurring solely upon the root surfaces following recession, this extension may be minimized. However, in mouths where much decalcification is present or those with erosion or abrasion cavities in the gingival third, it is well to extend the preparation in a less restricted manner.

Fig. 6.

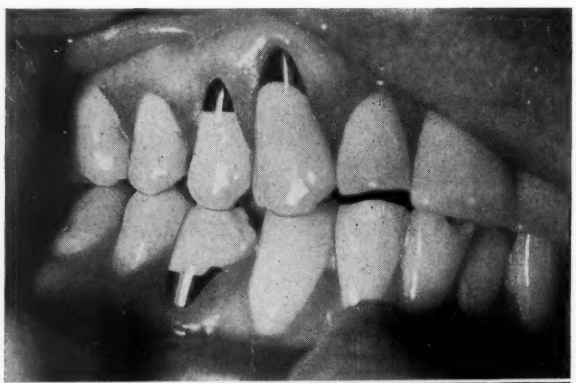

Fig. 7.

Fig. 8.

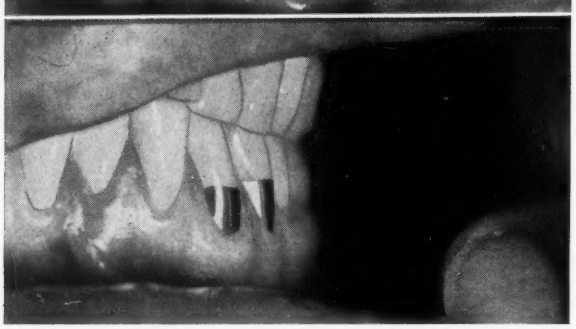

Fig. 6.—The three most common and practical Class V forms.

Fig. 7.—The buccal view of Class V restorations demonstrating tissue acceptance and extension into caries-free areas.

Fig. 8.—Anterior view of Class V restorations showing contour and occlusal wall levels.

The cavity walls are lined with cylinders of noncohesive foil, usually 1/16th in size, because: (1) they give finer adaptation to the walls, (2) they assist in filling the cavity more rapidly, (3) they protect the walls from a possible misstep

of the condenser, (4) they are easier to trim and finish, and (5), finally, when placed in this fashion, the density of the restoration may be easily maintained at a safe high level with a minimum of after condensation and burnishing. This is in contrast to the manipulation required of mat or crystalline golds to produce comparable densities.[2]

Large pellets of cohesive gold may be used at first to stabilize the cylinders in position. The subsequent pellets are built up in a concave form which wedges the gold toward the cavity walls until the final contour is achieved. This contour should be of a fullness to maintain the proper tone of the gingival tissue and to protect the tissue from the excursions of food. Here the normal curvature of enamel, as it approaches the cementoenamel junction, is worthy of duplication.

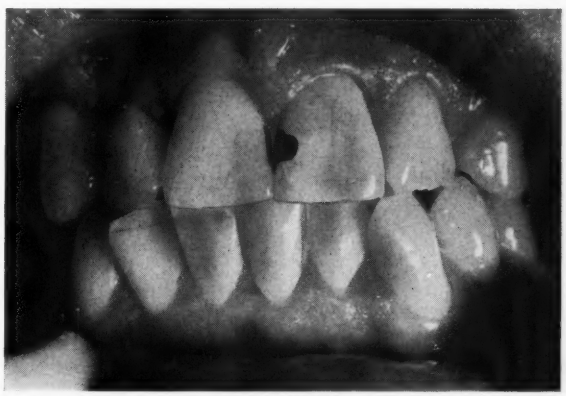

Fig. 9.—A modern Class III on the right central incisor in contrast to one fabricated over thirty years ago. (Patient and contemporary restoration through the courtesy of Robert J. Nelson, Washington, D. C.)

The Class III cavity of today has been refined greatly from the extensive outline forms seen in G. V. Black's time, though Black's sound principles must be followed for success. A view of the old and the new together in the same mouth (Fig. 9) is a graphic illustration in the trend to more esthetic Class III outlines. Some of the "invisible" techniques have been improved lately by the refinement of instruments to expedite the lingual approach (True[3] and Jeffery*). These instruments are made by standard manufacturers† and seem admirably suited to their purpose. Special extra long finishing strips are available again to aid fine and rapid finishing methods. Also study club tested, well-balanced gold knives are available, both for anterior and posterior restorations (Numbers 51, 52, 53, Univ. of Wash. Set B).

True,[3] Baird, Jones,[1] Fisher, and Smith,[4] all have designed hidden or inconspicuous Class III operations. Only two of these are intended for a mouth with an average tendency for caries activity. Most are intended to restore areas of incipient decay in mouths with little tendency toward decalcification.

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†O. Suter and Hartzell & Son.

The Ferrier Class III outline, on the distal surface of cuspids and lateral incisors, is a straight line and may be practically invisible when viewed anteriorly, solely because of the distal location. When the distal surface of a central incisor, or the mesial surface of the lateral or central incisor is involved, the outline is straight in the gingival two-thirds and parallel to the adjacent lobe of the tooth. It curves gracefully away in the incisal one-third. This form is classic, and gives the tooth a well-cared-for appearance without a blatant display of gold. The incisal edge is left well supported by strong enamel and dentine so that wear through the years will not jeopardize the incisal angle.

Gold foil manufacturers report an upswing in the sale of gold foil throughout the nation. The national meetings reflect it. The trend is to increased employment of this fine restorative material and to broader concepts in its use.

SUMMARY

1. Class I and Class V foil operations are discussed with stress on the salient variations in condensation and outline procedures.

2. The Class III classic forms and variations are discussed and new instruments are mentioned which aid in operating facility.

CONCLUSIONS

Gold foil is still unsurpassed as a restorative material. Modern concepts tend to increase the effective use of foil by aiding the esthetic result. An increased interest in foil by the profession is causing finer dentistry to be made available to the public.

REFERENCES

1. Jones, E. M.: Treatment of Initial Caries in the Anterior Teeth With Gold Foil, J.A.D.A. **26**:532-541, 1939.
2. Morrison, J. N.: University of Washington Dental School, Seattle, Wash.: Personal communication.
3. True, H. A.: Inconspicuous Class III Gold Foil Restorations, J.A.D.A. **30**:1352-1357, 1943.
4. Smith, B. B.: A Permanent and Esthetic Anterior Restoration, J.A.D.A. **40**:326-332, 1950.

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A CLINICAL CAMERA SETUP FOR THE GENERAL PRACTITIONER

CHARLES SCHROETER*

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OVER THE PAST DECADE photography of the oral cavity has become more and more important in the dental profession. As a visual aid for teaching and as a recording medium of the unusual case, the photograph or photographic slide has no equal. Many different cameras are available on the market. They fill every need, and the prices range accordingly. To achieve the most exacting results, a professional setup such as the one described by Gibson[1] is required. Occasionally, however, circumstances do not permit obtaining the service of a professional photographer. Time is usually the limiting factor. Many pictures of interesting clinical cases are missing from slide collections because a convenient camera setup was not available at the right moment.

In order to avoid this situation, it was decided to assemble a simplified clinical camera setup, which could be operated with only a basic knowledge of the laws of photography and by following a minimal set of rules. The component parts chosen are inexpensive. The ease of operation makes previous photographic experience unnecessary, and the resultant pictures are good. Teachers and practitioners in dentistry, who desire a clinical camera but who may be somewhat bewildered and discouraged by the complexity and the expense of some of the more elaborate apparatus, can readily assemble and unhesitatingly use the setup described herein (Fig. 1). The current cost of the entire assembly is approximately $75.00.

EQUIPMENT

1. *Camera.*—
   Kodak Pony 828.
2. *Camera Base and Frame Finders.*—
   Mayfair Automatic Lite.† Included are two wire frame finders which are interchangeable on the base.
3. *Extra Frame Finder.*—
   For extreme close-up photography an extra frame can be made by any instrument maker to these dimensions:
   Frame: 3 by 4 inches.
   Length of connecting rod: 6 inches.
   In order to facilitate the adjustment of the frame to the plane of critical focus, the length of the connecting rod must be variable. Once the proper distance has been established, the length of the rod is permanently secured with the set-screw.

Received for publication April 19, 1956.
*Director of Dental Photography; Instructor of Oral Anatomy.
†Made by the Mayfair Manufacturing Company, 89-93 Grand Street, Brooklyn 11, New York.

4. *Auxiliary Lenses.*—

One Eastman Kodak Portra Lens, 3+ diopters.
One Eastman Kodak Portra Lens, 5+ diopters.
One 10+ diopter lens, made to order by an optician.

5. *Adapter Rings and Lens Hoods, Series V.*—

An adapter ring is used to mount the auxiliary lens and the lens hood on the camera lens. For convenience and rapid exchange from one Portra lens to another it is advisable to acquire 3 adapter rings and 3 lens shades. Each Portra lens is assembled in an individual adapter ring and lens shade and thus is ready for immediate use.

6. *Light Source.*—

Two clear projection bulbs, 750 watt, 120V, T-20, C 13D, medium filament, are screwed into the lamp sockets. (Photoflood bulbs have insufficient output for the setup.)

EQUIPMENT ASSEMBLY AND METHOD OF ADJUSTMENTS

To assemble the component parts, the camera must be properly attached to the base. Settings for lens opening, distance, and exposure must be determined for each of the three sizes of photograph. It requires a little time and effort to make these determinations in the first place, but, once done, the work in connection with the use of this equipment is completed.

The camera is firmly attached to the Mayfair base. Three cardboards of the same size as the wire frames are cut out, and lines are drawn to indicate the center of the field (Fig. 2). The cardboards are taped to their respective wire frames and serve as test charts for visual focusing.

The back of the camera is removed, and a small piece of ground glass is taped to the opening of the picture frame with the ground side toward the camera lens. Thus, the ground glass is placed in the exact plane occupied by the film during the actual exposure.

The smallest frame for very close-up pictures with the cardboard taped to it is fastened to the camera base in the provided slot and tightened with the set-screw. The 10+ diopter Portra lens with the convex surface toward the front is mounted on the camera lens. The lens shutter is kept open by setting it to "B" and pressing the cable release. The winding lever must be kept in place to prevent the shutter from closing when the pressure on the cable release is discontinued. A matchstick or toothpick will serve the purpose. The assembly should be mounted firmly on a tripod, and a light must illuminate the cardboard of the frame finder. The lens diaphragm is opened to the widest stop, f/4.5. The camera is now ready to make all necessary adjustments.

When viewing the ground glass image, the center of the cardboard will usually not coincide with the center of the ground glass. The screw holding the camera to the base is loosened slightly, and the camera is shifted until the center of the field aligns horizontally with the center of the ground glass; but, at the same time, the camera should be in perfect alignment with the base. The

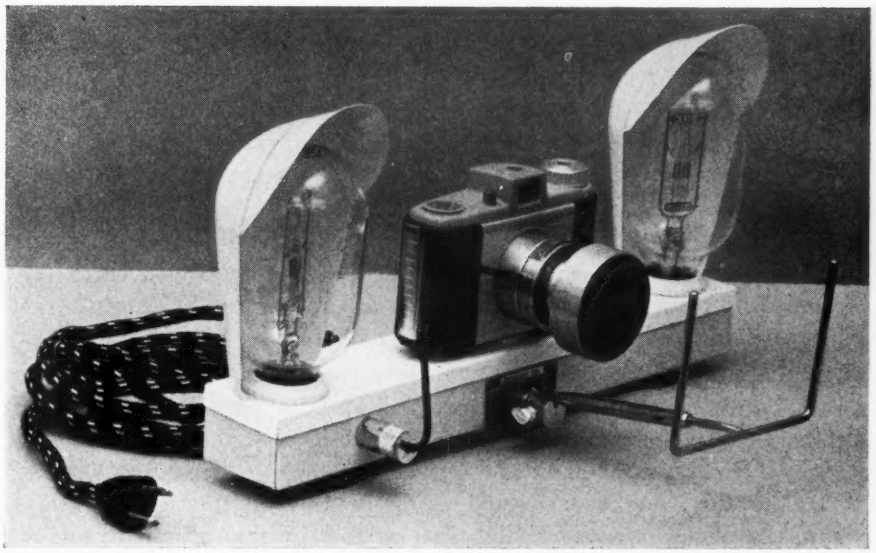

Fig. 1.—The unit, assembled for close-up photography.

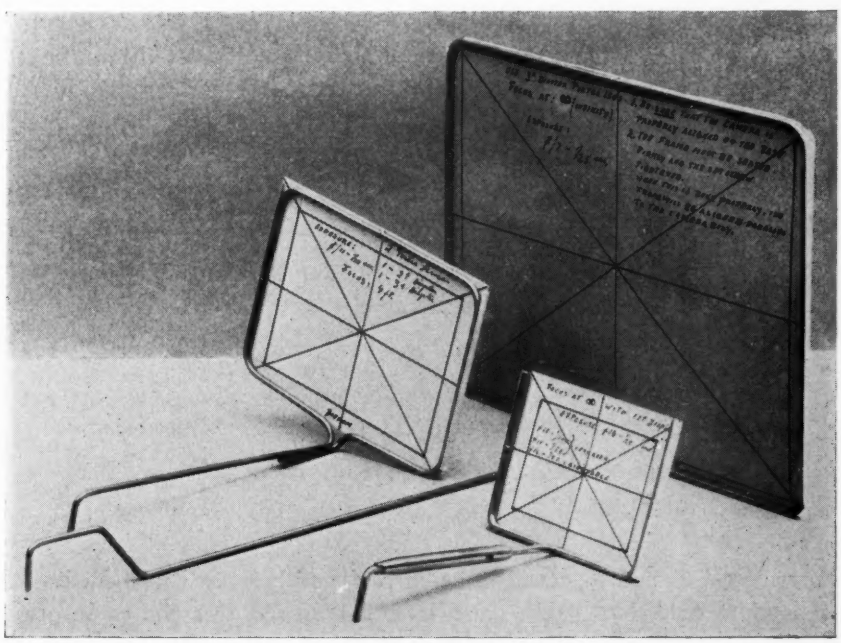

Fig. 2.—The frame finders with cardboards attached as used for proper alignment of the camera and for determining the exact focus.

vertical adjustment consists in bending the connecting rod of the frame at the angle near the slot. The focus of the lens is set at infinity, and the length of the adjustable connecting rod of the frame finder is changed until the lines of the cardboard are critically sharp on the ground glass. After these adjustments are completed, it is advisable to disconnect and replace the field frame finder several times and to examine the ground glass image for alignment after each change. This insures a correct seating of the finder when the other finders have been in use. The camera is now very securely fastened to the base and its position scribed on the latter. It is very important that the camera position is maintained in correct alignment with the base during its use. An occasional check on it is recommended. Correct focus will always be assured when the set-screw on the connecting rod of the frame finder is securely tightened.

It is necessary to position the two other frames in relation to the ground glass with the respective auxiliary lenses mounted on the camera lens. In adjusting the alignment of the other frames, the position of the camera must never be altered. All corrections are made by bending the wire frames either laterally or vertically. Focusing is performed easily by turning the camera lens while examining the picture on the ground glass with a magnifier and by taking records of these settings on the focusing scale. All data are written on the cardboard of the particular frame finder for which they were taken and are kept for future reference.

After the completion of the necessary adjustments, the cardboards are carefully removed from the frames, and the camera is ready to take trial exposures.

It is a very simple matter to determine the exposure time. One roll of color film will be enough to arrive at the proper exposure. The determination of correct exposure for Kodachrome Type A, Tungsten film, with the equipment illustrated, is recorded below as a guide.

A. The small frame finder and the 10+ diopter lens were mounted (Fig. 1), and eight exposures were taken with progressive lens openings and shutter speeds.

PICTURE	LENS OPENING	SHUTTER SPEED
No. 1	f/22	1/50 sec.
2	f/22	1/25 sec.
3	f/16	1/50 sec.
4	f/16	1/25 sec.
5	f/11	1/100 sec.
6	f/11	1/50 sec.
7	f/8	1/100 sec.
8	f/8	1/50 sec.

Exposures No. 4, 5, and 6 proved to be correct, and because it provided a slightly greater depth of field, No. 4 taken at f/16 and 1/25 sec. was chosen in preference to the others.

B. The correct exposure for the medium-sized frame, with the 5+ diopter Portra lens mounted and the camera lens focused at 4 ft. was found to be f/11 at 1/25 sec.

C. For the large frame, with the 3+ diopter Portra lens mounted, and the camera lens set at infinity, the correct exposure was found to be f/7 at 1/25 sec.

To prevent errors of assembly, the various components and diaphragm settings can be color coded. For example, the frame, Portra lens, focus scale, and f/stop can be marked in red for assembly A, green for assembly B, and yellow for C. An operating chart should be kept with the camera for reference.

OPERATING CHART

ASSEMBLY	COLOR CODE	FRAME FINDER	PORTRA LENS	FOCUS	LENS OPENING	SHUTTER SPEED
A	Red	Small	10+	Infinity	f/16	1/25 sec.
B	Green	Medium	5+	4 feet	f/11	1/25 sec.
C	Yellow	Large	3+	Infinity	f/7	1/25 sec.

PROCEDURE FOR OPERATING THE CLINICAL CAMERA

The cable release must be connected between the base and the camera, and the latter is loaded with Kodachrome Type A film. The Kodak Pony camera takes an eight-exposure roll of film. This is an advantage for the slides are available more quickly than if one must wait for 20 or 36 exposures to be made.

Fig. 3.—The clinical camera in use.

Assembly A is used as an example (Fig. 3).

1. The small frame finder (marked in red) is mounted to the base.
2. The 10+ Portra lens with lens hood (marked in red) is mounted on the camera lens.
3. The camera lens is focused at infinity (red mark).
4. The diaphragm is set at f/16 (red mark).

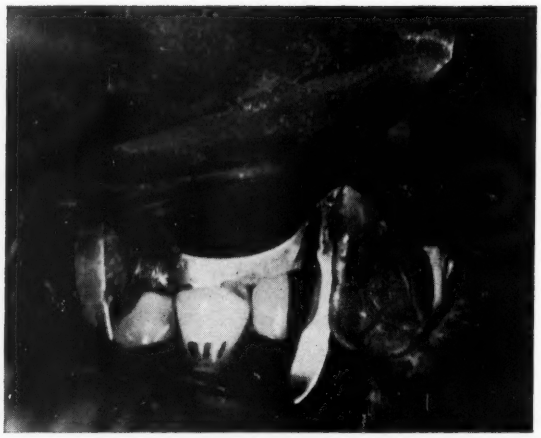

Fig. 4.—A typical result, using the medium assembly. (Reproduced from a Kodachrome transparency.)

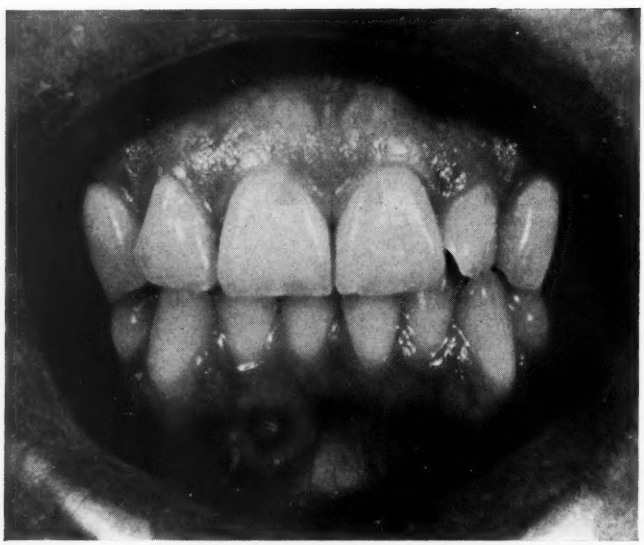

Fig. 5.—A typical photograph, using the close-up assembly. (Reproduced from a Kodachrome transparency.)

5. The shutter speed is set at 1/25 sec. (red mark).
6. The shutter is wound.
7. The camera is steadied with elbows pressed firmly against the body while the field to be photographed is sighted in the frame finder (Fig. 3).
8. The patient is told to keep his eyes closed.
9. The release button is partially depressed until the lights are on and is held in this position one full second to obtain maximum light output. Then the button is slowly squeezed to release the shutter.
10. The film is wound immediately to the next frame.
11. All necessary data are entered in the exposure record.

Usually the camera is assembled for a given frame. In that case only 4 steps have to be remembered, namely:

1. Cock the shutter.
2. Make the exposure.
3. Turn the film to the next frame.
4. Enter the necessary data.

It becomes truly a very simple matter to take color photographs of any part of the human denture with such a setup. Figs. 4 and 5 show sample results.

CONCLUSION

Photography has become an increasingly important adjunct to clinical records in dentistry. Many practitioners, perhaps because of limited experience with the complex, professional type of photographic equipment, are not availing themselves of the advantages of routine use of photographic prints or slides of their cases.

A clinical camera setup has been described which is easy to assemble, inexpensive, and extremely easy to use.

REFERENCE

1. Gibson, H. L.: Kodak Flurolite Camera Combination and Flurolite Enlarger, D. Radiog. & Photog. **23**:3, 50-53, 1950.

School of Dentistry
University of Washington
Seattle 5, Wash.

Readers' Round Table

FITZSIMONS ARMY HOSPITAL
DENVER, COLORADO

Editor, THE JOURNAL OF PROSTHETIC DENTISTRY:

To a resident in prosthodontics, like myself, the publishing of the "Glossary of Prosthodontic Terms" in the March issue of THE JOURNAL OF PROSTHETIC DENTISTRY represents a major contribution. It was stated that constructive suggestions were invited. Since this compilation of terms will undoubtedly become a "textbook" for students of prosthodontics, it is respectfully suggested that additional consideration be given to the listing of *technique* as preferred and *technic* as objectionable (p. 30). References consulted included Webster's Unabridged *Dictionary* and the *Oxford English Dictionary*. For the following reasons technic would seem preferable:

1. Both words are synonomous in meaning and context.

2. Technic is derived from the Greek, while technique is of French origin. The very basic word prosthesis is of Greek origin. Again, words such as technical and technician have technic as a base, not technique.

3. Derived words which may become acceptable in the future will use technic as a base, not technique. The words psychotechnics and electrotechnics are examples. The word prosthotechnics would seem plausible.

Truly yours,

RALPH W. FLINCHBAUGH
Major (DC)

LONG ISLAND CITY, N. Y.

Editor, THE JOURNAL OF PROSTHETIC DENTISTRY:

Knowing something about the history of past efforts to establish a standard nomenclature in prosthodontics, I feel that the publication of the "Glossary of Prosthodontic Terms" is a notable achievement and deserving of every approbation.

However, I have one small ossicle to pick with the reference to the "Pleasure curve." I fully agree that the term itself is objectionable; it has connotations of sensuality that are more readily associated with Gina or Marilyn than with dental occlusion. Besides this, eponymic terms are to be deplored on principle, as lacking in descriptiveness. But these are minor considerations.

A more serious matter is the definition of the "Pleasure curve" as identical with the "reverse curve," which, significantly, is defined in terms that are misleading (p. 28). I have advocated "an alignment of the occlusal surfaces of (some of) the teeth which is convex upward" in the frontal plane, but neither I, nor anyone else I know of, has ever advocated a curve convex up-

ward in the sagittal plane. That would be a perversion of all we have observed about gliding mandibular movements, and about balanced occlusion. It is notable also that the glossary omits reference to the Avery brothers, who were the first to advocate a reverse curve in the frontal plane. And I find no reference to the curve of Wilson.

For the record, the occlusal alignment I have described requires a "reverse" curve (convex upward) in the frontal plane through the premolar and first molar area to help stabilize the lower full denture during mastication, plus a "Monson curve" (concave upward in the frontal plane) through the second molars for balance in lateral and protrusive gliding movements. In the *sagittal* plane, such an arrangement always produces a well-marked conventional compensating curve (concave upward). In short, it is a combination of the Avery and the Monson curves with the curve of Spee thrown in, not just for good measure, but with the deliberate purpose of balancing the descent of one or both condyles down the slope of the articular eminence.

I trust that means can be found to correct the definition of "reverse curve" in so far as it refers to a convexity upward in the sagittal plane, or else to so define the "Pleasure curve" that its true shape will be clearly demarcated from the stated definition of the reverse curve.

Cordially yours,

MAX A. PLEASURE, D.D.S.

Editor's Note:

Further suggestions on prosthodontic terminology and definitions are welcome. They should be directed to the Editor, who will place them in the hands of the Nomenclature Committee of the Academy of Denture Prosthetics.

News and Notes

ANNOUNCEMENTS

The next meeting of the American Denture Society will be held at the Traymore Hotel at Atlantic City, Sept. 28 and 29, 1956. Hotel reservations must be made through the American Dental Association Housing Bureau.

The Greater New York Dental Meeting will be held Dec. 3 to 7, 1956, at the Hotel Statler in New York City.

The Ohio State University College of Dentistry announces that it is receiving applications of students for the Curriculum of Dental Laboratory Technology. This course of study of the laboratory phases of prosthodontics extends over two academic years and leads to a Certificate of Graduate Dental Laboratory Technologist. For further information write to the Chairman of Dental Laboratory Technology, Ohio State University College of Dentistry, Columbus 10, Ohio.

Temple University School of Dentistry announces a two weeks' course in Advanced Orthodontics under the direction of Dr. Robert H. W. Strang beginning January 20, 1957. Application material and information may be obtained from Dr. Louis Herman, Director of Postgraduate Studies, Temple University School of Dentistry, 3223 North Broad Street, Philadelphia 40, Pa.

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Vol. 6, No. 5, September, 1956. Journal of Prosthetic Dentistry is published bi-monthly by the C. V. Mosby Company, 3207 Washington Blvd., St. Louis 3, Mo. Subscription rates: United States and Its Possessions $10.00, Students $5.00; Canada, Latin-America, and Spain $10.50, Students $5.50; Other Countries $11.00, Students $6.00. Single copies, $2.50 postpaid. Entered as second-class matter March 13, 1951 at the Post Office at St. Louis, Missouri, under the Act of March 3, 1879. Additional entry authorized at Jefferson City, Missouri. Printed in the U. S. A.

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